I-90 Snoqualmie Pass Wildlife Habitat Linkage Assessment

Final Report

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Prepared by
Peter H. Singleton and John F. Lehmkuhl

U.S. Department of Agriculture
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Executive Summary

Work on the Snoqualmie Pass I-90 Wildlife Linkage Assessment started in January 1998 and was completed in March 2000. The primary objectives of this project were to:

> 1) Determine the nature of highway and road barrier effects on animal movements and populations, and
> 2) develop a landscape-scale methodology for integrating wildlife conservation and human safety in transportation corridors (Lehmkuhl 1997).

This report reviews the findings of this project and presents strategies for maintaining and enhancing landscape permeability for wildlife in the vicinity of I-90 near Snoqualmie Pass.

Literature Review

A literature review was compiled and will be submitted for publication in 2000. A bibliography of approximately 1200 citations on the interactions of wildlife and roadways was posted on the Wenatchee Forestry Sciences Lab web site in January 1999.

Landscape Modeling

GIS landscape linkage models were developed for 4 different groups of wildlife. Habitat linkage patterns predicted by these models are strongly influenced by urban and suburban residential development in the Yakima River Valley bottom and by historic timber harvest patterns in the area south and west of Keechelus Lake. These landscape characteristics channel predicted habitat linkage into the vicinity of Easton Hill for high and moderate mobility species.

Camera Surveys

Data was compiled for 132 automatic camera stations. Eighty stations were conducted during this study from September 1998 to March 2000. Data from 51 stations conducted by national forests from September 1995 to August 1997 near the I-90 study area were compiled. Nineteen species were detected during camera surveys, including mule deer, Douglas squirrel, bobcat, black bear, snowshoe hare, elk, northern flying squirrel, coyote, American marten, chipmunks, stripped skunk, mountain lion, weasel, porcupine, bushy-tailed woodrat, spotted skunk, beechy ground squirrel, domestic dog, and humans. Mountain lion were not detected at camera stations within 1 mile of the highway. Mule deer were more commonly detected during the summer and were detected more often within 1 mile of the highway. Bobcat and coyote were more commonly detected during winter and were detected more often within 1 mile from the highway. Bobcats, coyotes, and black bears were detected most frequently in the vicinity of Easton Hill, Amabalis Mtn., and the south end of Keechelus Lake (milepost 60 – 69) and were rarely detected within 1 mile of the highway in the Yakima Valley (milepost 69 – 81),.

Deer and Elk Road-kill Distribution

Road-kill distribution was mapped along 54 miles of I-90, from milepost 35 to milepost 89 using data collected by WSDOT maintenance personnel from 1990 to 1998. Three hundred and forty-five deer and 102 elk kills were located within the study area (mileposts 52 to 81). Four road-kill concentration areas were identified; the north end of Keechelus Lake (mileposts 55 to 56), the south end of Keechelus Lake (mileposts 61 to 63), Easton Hill (mileposts 67 to 69), and the Cle Elum River (mileposts 80 to 82). Habitat characteristics of deer and elk kill locations were analyzed and are presented in this report.

Snow Tracking Surveys
Snow tracking surveys were conducted along I-90 from January to March 1999 and 2000. Each highway section was surveyed 5 to 8 times each year. A total of 518 animal detections were recorded during approximately 250 miles of snow tracking. Coyote and bobcat were the most commonly detected species, and were more frequently detected along Easton Hill, Amabalis Mtn., and south end of Keechleus Lake (milepost 60-69). Coyote and bobcat were detected substantially less often in the Yakima Valley (milepost 69-81) than in other portions of the study area. Highway crossings recorded during snow tracking included 49 crossings by coyote, 13 crossings by bobcat, and 5 crossings by raccoon. Crossing locations were relatively clustered in distribution, with 66% of all crossings occurring in 8 areas totaling approximately 2.5 miles of highway. Crossing clusters were located along Easton Hill (milepost 67-69) and in the vicinity of the Stampede Pass exit (at mileposts 62 and 63.5).

Highway Structure Monitoring
Highway structures were inventoried and monitored for animal use from May to October 1998. Monitoring was conducted at 5 bridges and 24 drainage culverts. The drainage culverts ranged in size from 0.4 to 1.7 meters in height and were monitored during the summer dry season. Fifteen species of mammals were detected crossing I-90 through highway structures. Mice, chipmunks, Douglas squirrels, stripped skunk, bushy-tailed woodrat, and mule deer were the most commonly recorded species. Raccoon, hoary marmot, weasels, snowshoe hare, opossum, river otter, American marten, and porcupine were recorded less frequently. Small mammal trapping was conducted in and adjacent to dry drainage culverts in August 1999. Ten species were trapped in the culverts. Deer mice were the most common species trapped in culverts. Structure and adjacent habitat characteristics of culverts used by wildlife varied by species. Dry drainage culverts, 0.4 to 1.1 meter diameter, were regularly used by small mammals for crossing I-90.

Discussion
Areas of the I-90 corridor with greater landscape permeability relative to adjacent areas were identified from the landscape modeling and field data compiled for this project. These areas are:

- The cascade crest area with potential connectivity at airplane curve (milepost 51), the corners of sections 10 and 16, T22N, R11E (milepost 54), and the north end of Keechelus Lake (milepost 55).
- The Keechelus Ridge / Swamp Lake area with connectivity at the south end of Keechelus Lake and in the vicinity of the Stampede Pass exit (mileposts 61 to 64).
- Easton Hill (mileposts 67 to 69).
- Areas east and west of Lavender Lake (mileposts 71 and 72.5)

- The Cle Elum River (milepost 81).

Strategies for Managing Landscape Permeability

I-90 passes through a number of elevation and precipitation zones. Different varieties of wildlife are present in the different zones. Landscape permeability should be maintained at intervals through the length of the highway to provide for animal movement in each elevation and precipitation zone. Permeability should be addressed at two scales; 1) the landscape, by maintaining or restoring habitat that can provide for landscape-scale animal movements during which animals are likely to encounter the highway, and 2) the highway, by providing crossing structures for animals to cross the highway at appropriate locations. The areas with greater relative landscape permeability identified in this report are expected to be good locations for highway crossing structures.

Crossing opportunities for both large, high mobility species and small, low mobility species should be provided along the highway. Results of highway structure monitoring in this study indicate that dry drainage culverts provide opportunities for small mammal movement across the highway. Provision of such crossing opportunities, particularly in areas adjacent to late successional forest, may facilitate old forest ecological functions involving small mammals (e.g. the dispersal of seeds and fungal spores).

1) Introduction

Highways and associated developments can have substantial influence on animal movement patterns (for example Beier 1995, Gibeau and Herrero 1998, van Riper and Ockenfels 1998). Highway barrier effects can influence wildlife distribution by changing intra-territorial and dispersal movement patterns. Disruption of intra-territorial movement can contribute to a loss of available habitat (e.g. Mansergh and Scotts 1989). Disruption of dispersal movements can isolate populations and increase the probability of local extinctions (e.g. Mader 1984). In either case, highway barriers can have negative effects on some species (Andrews 1990, Reh and Seitz 1990, Foster and Humphrey 1992). Barrier effects are likely to be amplified by human disturbance and changes in habitat configuration and composition resulting from past resource management practices, residential development, and recreation (Forman 1995).

In Washington State, 1 area of particular concern regarding highway barrier effects is the Interstate 90 corridor over Snoqualmie Pass, east of Seattle in the central Cascade Mountains (figure 1.1). In 1994, the President's Northwest Forest Plan was implemented to address forest management issues on federal lands in the Pacific Northwest (USDA Forest Service 1994). The plan designated 10 'Adaptive Management Areas' (AMAs), including the east side of Snoqualmie Pass (USDA Forest Service 1997). Late Successional Reserve (LSR) areas, to be managed for old forest characteristics, were also designated under the plan. Because Snoqualmie Pass is a "keystone" area in regard to federal lands, particularly those designated as LSR and wilderness areas, the Northwest Forest Plan states that the planning emphasis for the Snoqualmie Pass AMA is the "development and implementation … of a scientifically credible comprehensive plan for providing late-successional forest on the checkerboard lands. This plan should recognize that the area is a critical connective link in the north-south movement of organisms in the Cascade Range" (Record of Decision D-16, USDA Forest Service 1994). An extensive land exchange was recently completed to consolidate federal land holdings in this area for management for ecosystem connectivity (USDA Forest Service 1999).

In light of this management mandate, the U.S. Forest Service, Pacific Northwest Research Station and the Washington State Department of Transportation (WSDOT) entered into a cooperative agreement to conduct research on the effects of the Interstate 90 corridor on wildlife movement. Funding for this project has been provided by The Washington State Department of Transportation and USDA Forest Service under USDA Forestry Sciences Lab Cooperative Agreement PNW-98-0513-CC and Washington Department of Transportation Contract No. GCA1177.

Work on the Snoqualmie Pass / I-90 Wildlife Linkage Assessment started in January 1998 and was completed in March 2000. The focus of this project was to assess the barrier effects of a major interstate highway, at multiple scales, for a variety of species, in the context of a highly fragmented landscape. The primary objectives of this project were to: 1) Determine the nature of highway and road barrier effects on animal movements and populations, and 2) Develop a landscape-scale methodology for integrating wildlife conservation and human safety in transportation corridors (Lehmkuhl 1997). At least two scales are critical for evaluating landscape permeability in the vicinity of a major highway corridor like interstate 90: 1) Landscape-scale habitat connectivity patterns potentially channel animal movement in the vicinity of the highway, and 2) Animals are more likely to cross the highway in locations where highway configuration or structures provide opportunities for passage. We attempt to address both of these scales in our assessment.

1.1) Study Area

Our study focuses on 30 miles of highway from Snoqualmie Pass, at the crest of the Cascade Mountain Range (elev. 3000 feet), to the eastern edge of contiguous forest at the town of Cle Elum (elev. 2000 feet, figure 1.1). The study area is characterized by rugged mountainous topography. Peaks adjacent to the highway at the pass reach elevations up to 6278 feet. These rugged peaks along the Cascade crest create a substantial 'rain shadow' effect, with the western portion of the study area receiving 140 inches of precipitation each year and the eastern portion receiving 30 inches (USDA Forest Service 1997). Snow accumulation can reach 30 feet at the pass, while rarely exceeding 3 feet near Cle Elum.

Because of the substantial elevation and precipitation gradient, the study section of the highway passes through a variety of vegetation zones and associated wildlife communities. Species of concern in this area range from highly mobile carnivores to low mobility organisms associated with old forests. Wolverine (*Gulo gulo*) and lynx (*Lynx canadensis*) are present in the central Washington Cascades, and have been recorded on both sides of the highway (Wenatchee National Forest, Cle Elum Ranger District unpublished data). Fisher (*Martes pennanti*) were detected in the area as recently as 1976. Possible detections of grizzly bear (*Ursus horribilis*) and wolf (*Canis lupus*) have also been recorded in this area. Management directives included in the Northwest Forest Plan require surveys for a variety of species that have received little attention in the past, for example Oregon megomphix land snail (*Megomphix hemphilli*), blue-grey tail-dropper (*Prophysaon coeruleum*), keeled jumping slug (*Hemphillia burringtoni*) and others. These surveys have contributed to our understanding of late-successional forest ecosystems in this area. Readers are urged to refer to the I-90 Land Exchange Environmental Impact Statement (USDA Forest Service 1999) for an extensive discussion of the affected environment and species of management concern in our study area.

The configuration of forest habitat in the Snoqualmie Pass area has been influenced by a variety of historic factors. The land grant made by the federal government to the Northern Pacific Railway Company in the 1864 was an especially important factor. Every other square mile of land along the route of the rail line was deeded to the railroad. Most of these lands were sold to recover the cost of building the rail lines, however some mountainous forested lands were retained by the rail company and became commercial timberlands. This resulted in a checkerboard land ownership pattern across much of Snoqualmie Pass. Different management objectives between the public and private ownerships have resulted in a highly fragmented forest landscape. An extensive land exchange was recently completed to consolidate land holdings in this area (USDA Forest Service 1999).

In addition to the highway and timber harvest, other features influence landscape permeability for wildlife. Two high voltage electrical transmission lines and a railroad traverse the study area. The Yakima River valley bottom in the eastern portion of the study area is experiencing substantial suburban residential development. For the residents of urban communities around Seattle, Snoqualmie Pass is one of the most accessible areas for outdoor recreation, and there is an extensive ski resort development at the top of the pass.

Interstate 90 is a high-volume, high-speed roadway. Highway configuration in our study area ranges from 4 lanes in each direction, separated by a concrete median barrier, to 2 lanes in each direction separated by a broad forested median. Average daily traffic volume through the study area is approximately 24,400 vehicles with an average daily peak volume of 3920 vehicles per hour (including both east and west bound traffic) (Jim Mahugh, WSDOT South Central Region Traffic Office, pers. commun.). By 2018 these volumes are projected to increase to 41,400 vehicles per day with peak volumes of 6190 vehicles per hour. Highway expansion is planned to meet the increased need.

Despite the substantial impacts along the highway corridor, I-90 passes through a relatively narrow gap between large blocks of land managed primarily for conservation and recreation. The Alpine Lakes Wilderness Area is less than 1 mile north of the highway in some places, while the Norse Peak Wilderness Area lies at least 15 miles to the south. LSR areas designated by the Northwest Forest Plan are located approximately 1 mile south and 7 miles north of the highway.

1.2) Project Components

The purpose of our project is to assess landscape permeability at multiple scales, for a variety of species, through a highly fragmented landscape. The project consists of 5 components; 1) landscape-scale habitat connectivity modeling, 2) analysis of road-kill distribution, 3) monitoring animal use of existing highway structures, 4) conducting automatic camera surveys in the vicinity of the highway, and 5) winter snow tracking surveys along the highway. The project components investigate the question of landscape permeability at different scales. Landscape-scale linkage modeling identifies where animals are likely to encounter the highway based on coarse-scale habitat connectivity. Automatic camera surveys provide information on what species are present near the highway and where those species occur. Analysis of road-kill distribution, snow tracking surveys, and highway structure monitoring provides information on specific locations where animals cross or attempt to cross the highway. By combining these components we have attempted to develop an understanding of wildlife distribution and movement patterns that can be incorporated into highway design to increase landscape permeability for wildlife and improve highway safety. In this report we will present the methods and results from each project component, summarize these results in the discussion of connectivity areas along the highway, and conclude by identifying strategies that could be implemented to maintain and enhance landscape permeability for wildlife in the study area.

1.3) Highway Sections

To stratify the highway for field monitoring of wildlife distribution (i.e. camera surveys, snow tracking surveys, and highway structure monitoring), we split the highway into 6 segments based on landscape and highway characteristics (figure 1.2). The segments are:

- **Section 1, Yakima Valley:** Cle Elum to Lake Easton (mp 69.5-81) - This segment is characterized by relatively flat valley bottom with mixed suburban development, pasture, agriculture, and upland dry forest. It is located in the vicinity of the Easton Ridge corridor identified in the I-90 Land Exchange EIS (USDA Forest Service 1999).
- **Section 2, Easton Hill:** Easton State Park to Amabalis Mtn. (mp 67-69.5) - Easton Hill is a broad forested slope. The widely divided highway with a forested median is unique within the study area. This area is transitional between the dry forest types to the east and more mesic forests to the west.
- **Section 3, Amabalis Mtn.:** Easton Hill to Cabin Creek (mp 64-67) - This segment runs through steeply sloping mid-elevation fragmented mesic forest on the southwest side of Amabalis Mountain. There is a Jersey barrier in the median and steep embankments on the north side of the highway throughout this segment.
- **Section 4, Keechelus South:** Cabin Creek to Keechelus Lake (mp 60.5-64) - This segment corresponds to the Swamp Lake – Lodge Creek valley. The adjacent landscape is relatively flat with fragmented mesic to wet forest and there are no Jersey barriers in the median. This area was identified as the Keechelus Ridge corridor in the I-90 Land Exchange EIS (USDA Forest Service 1999).
- **Section 5, Snoqualmie Pass:** Gold Creek to Snoqualmie Summit (mp 52-55.5) - This segment is characterized by high elevation wet forest, a substantially wider roadway, and significant recreational development. This area was identified as the Cascade Crest corridor in the I-90 Land Exchange EIS (USDA Forest Service 1999).
- **Section 6, Keechelus Lake:** (mp 55.5-60.5) - The highway runs along the east shore of the lake through this segment. The lake is approximately 1 mile wide and 5 miles long. This area is considered to be an impermeable barrier to animal movement because of the lake.

We excluded the Keechelus Lake segment (section 6) from field monitoring efforts because the lake blocks connectivity between habitat on either side of the highway.

I-90 Snoqualmie Pass Study Area

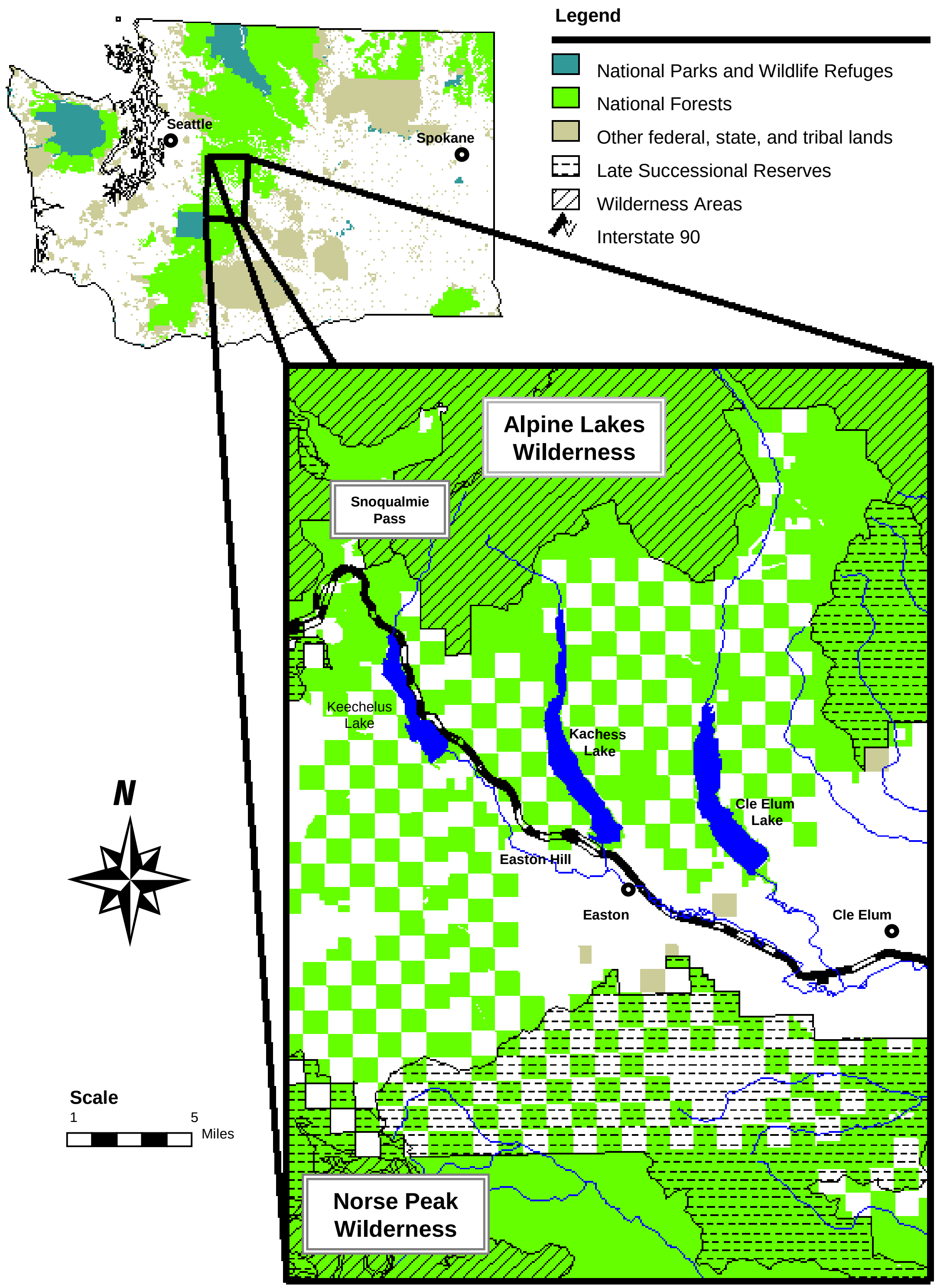


Figure 1.1. I-90 Snoqualmie Pass landscape connectivity modeling study area and regional location map.

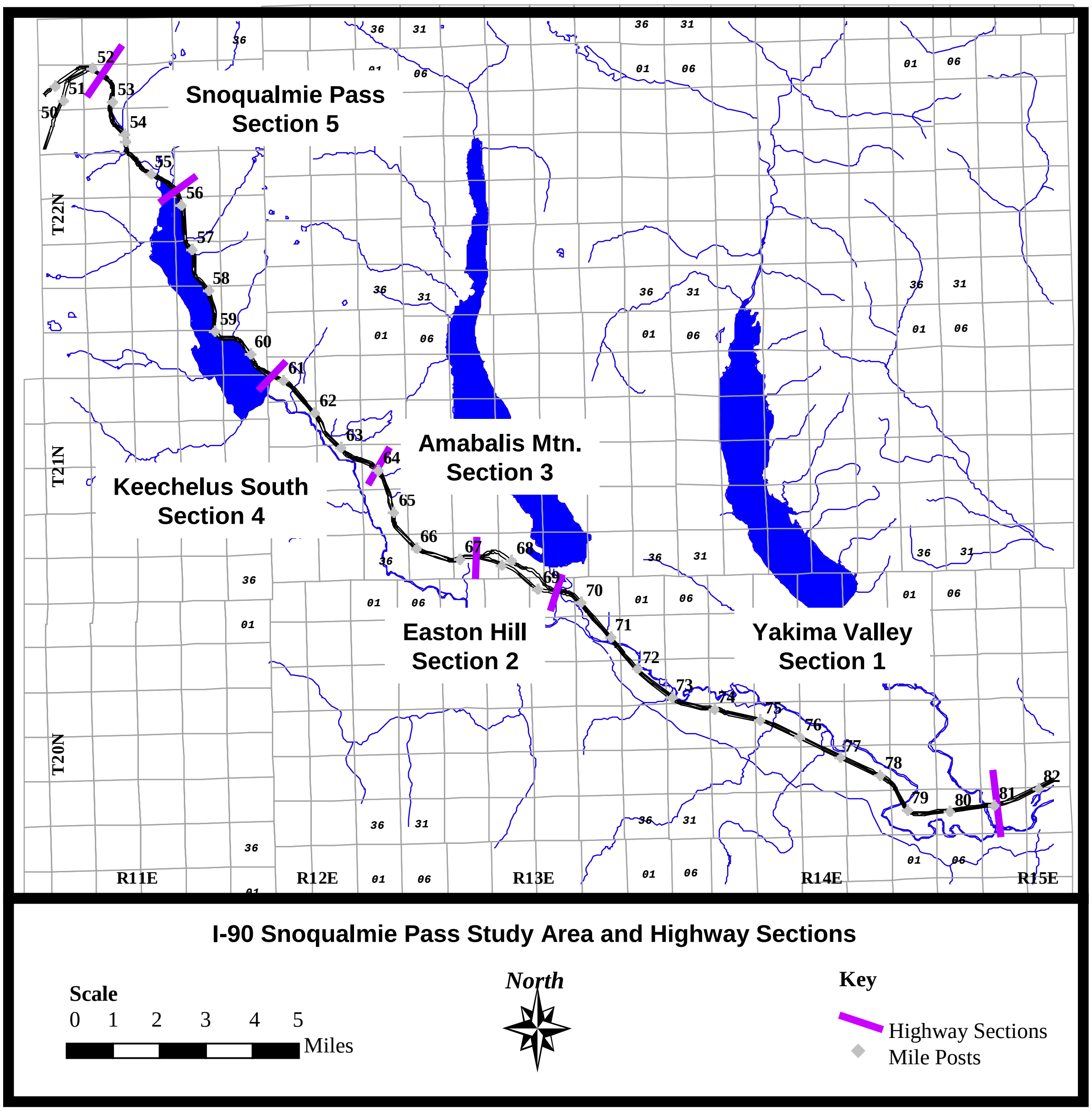


Figure 1.2. The I-90 study area and highway sections used for stratifying automatic camera surveys, snow tracking surveys, and highway structure monitoring.

2) Literature Review

An extensive bibliography (approximately 1200 citations) on the interaction of wildlife and roadways was compiled during winter and spring of 1998. A summary paper was written from this information during summer 1998. This report, entitled "Wildlife-Roadway Interactions: A bibliography and review of roadway and wildlife interactions" (Singleton and Lehmkuhl 1998), was delivered to WSDOT in December 1998. Readers interested in a more complete discussion of the impacts of highways on animals are urged to refer to this report. The bibliography was posted on the Wenatchee Forestry Sciences Lab web site (www.fs.fed.us/pnw/wenlab/research/projects/wildlife) in January 1998. A PNW Research Station General Technical Report is in preparation based on this material and will be submitted for publication.

3) Landscape Modeling

3.1) Introduction

Our objectives in conducting landscape-scale habitat connectivity analysis were to identify potential habitat linkage areas in the vicinity of I-90, and to produce a methodology for identifying habitat linkage patterns that may be applicable for forested landscapes in the Cascades region. Animals disperse in a variety of ways, but certain habitat characteristics such as forest cover and human disturbance are believed to influence the selection of dispersal routes for some animals (for example Beier 1995, Gustafson and Gardner 1996). Identification of habitat connectivity areas at the broadest scale provides information on where animals are likely to encounter the highway.

3.2) Methods

Because of the difficulty of modeling for numerous individual species and the limitations of the available geographic data, we based our analysis on 4 primary types of dispersers of interest to landscape managers in the Pacific Northwest. These types, or dispersal guilds, were; 1) high mobility dispersal habitat generalists sensitive to human disturbance, 2) moderate mobility late successional associates, 3) low mobility late successional associates, and 4) low mobility late successional riparian associates. Representative species, key characteristics, and model parameters for each of these guilds is presented in table 3.1.

GIS landscape data layers for linkage modeling were gathered from Wenatchee and Mount Baker – Snoqualmie National Forest corporate data (table 3.2, figure 3.2). Because of concerns about data accuracy and differences in geographic extent of the data, we ran the models with 2 different classified landsat images for vegetation data. Classified landsat images from the Wenatchee National Forest and Boise Cascade Corp. were used in the linkage modeling. Results from model runs with the 2 data sets were very similar.

Our modeling approach is based on “least-cost” path analysis conducted with the ArcInfo GRID module. Least-cost path analysis assigns a cost to each map cell in the GIS grid map. Cumulative cost (the sum of the costs of all cells traversed) from a designated source is then calculated for each cell. This technique has been used to evaluate landscape-scale wildlife habitat connectivity in Montana (Walker and Craighead 1997) and eastern Europe (Kobler and Adamic 1999). Our approach uses a breeding habitat suitability model to identify areas that are likely to support breeding populations of the subject species (source areas), and a dispersal habitat suitability model to calculate cost values for each cell (figure 3.1). The breeding and dispersal habitat suitability models vary according to guild (table 3.1).

3.3) Results

Maps from the habitat linkage analysis are shown in figures 3.3 through 3.6. Predicted linkage areas were centered on Easton Hill (sections 32, 33, and 34, T21N, R13E), particularly for the moderate and high mobility guilds. In this area, the forested state park lands on the west side of Easton Lake were an important linkage between the forested lands east of Cabin Creek on the south side of the highway, and the forested lands on the south and east sides of Kachess Lake north of the highway. Secondary connectivity areas were also identified along the west side of the Cascade Crest (approximately section 36, T23N, R10E to section 36, T20N, R10E) and at the south end of Keechelus Lake (approximately section 3, T21N, R12E to section 31, T21N, R11E). Two broad landscape characteristics appear to be driving the linkage model results; 1) the historic timber harvest patterns and road density in the area south and west of Keechelus Lake, and 2) residential development in the Yakima River valley bottom between Easton and Cle Elum. This combination of characteristics appears to direct the predicted linkage routes into the Easton Hill / Amabilis Mountain area. Retention of scattered forest patches along the Cascade Crest and in sections 14 and 22 (T21N, R11E) southwest of Keechelus Lake may provide some habitat for animal movement through these areas.

Estimates of overall permeability for animals moving across the study area varied substantially between dispersal guilds. Using minimum cumulative costs for traversing the corridors identified by the linkage models as an index of landscape permeability, the linkage models predict that the I-90 Snoqualmie Pass study area is most permeable for high mobility dispersal habitat generalists and least permeable for low mobility late successional riparian associates. Despite the identification of comparatively broad linkage areas for late successional riparian associates, travel through these areas is estimated to be relatively difficult for these species.

While the landscape linkage models developed for this project appear to be useful tools for investigating landscape patterns in the study area, a number of limitations of the models must be acknowledged. Our primary concern is the quality of the geographic data layers, particularly regarding vegetation. Accuracy of the landsat TM images used here has been estimated at approximately 70% for canopy closure and 60% for tree size (Pat Murphy, Wenatchee National Forest GIS Coordinator, Pers. Commun.). However, the similarity of the linkage patterns predicted by the 2 classified TM images used here suggests that these data sets identify similar broad-scale patterns that actually exist on the ground.

Also of concern is the spatial resolution of the data. Thirty meter resolution data is probably adequate for assessing habitat for the high and moderate mobility species, however the low mobility species are probably selecting habitat based on structural characteristics that cannot be directly identified from satellite images (e.g. down woody debris). These models should be considered hypothesis development tools that can help identify landscape patterns that may direct animal movement, but particularly for the low mobility guilds, the difference between data resolution and the scale at which the modeled species selects habitat is cause for caution.

It is also important to remember that these models do not address roadway characteristics that may prevent animal movement across the highway. While these models can complement and assist in developing field monitoring strategies, these models should not be considered a substitute for field verification of actual animal movement, crossing patterns, and distribution in the landscape.

Table 3.1. Representative species, key characteristics, and model parameters for I-90 Snoqualmie Pass Linkage Assessment habitat linkage modeling guilds.

<table>
<tr><th colspan="2">High Mobility Dispersal Habitat Generalists</th></tr>
<tr><td colspan="2">Representative species: Wolverine (Gulo gulo), Grizzly Bear (Ursus horribilis), Lynx (Lynx canadensis), Wolf (Canis lupus)
• Model patterned after Servheen and Sandstrom (1993) Grizzly Bear linkage model (without riparian area interaction).
• Dispersal of these species is more influenced by human disturbance than by habitat structure.</td></tr>
<tr><th>Source Model Parameters</th><th>Dispersal Model Parameters</th></tr>
<tr><td>Large roadless areas associated with wilderness (similar to grizzly bear core areas, but uses road density rather than buffered road coverage, and does not account for trails).</td><td>Road Density (RD)
<1mi/ mi^2 = good (1)
1-2mi/ mi^2 = mod (0.75)
>2mi/ mi^2 = poor (0.5)
Building Density (BD)
<10/ mi^2 = good (1)
10-50/ mi^2 = mod (0.75)
>50/ mi^2 = poor (0.1)
Canopy Closure (CC) (hiding cover)
>30 or 40% = good (1.5)
<30 or 40% = no effect (1)

Model Form
(((RD * CC) >1 reclassed to 1)BD)</td></tr>
<tr><th colspan="2">Moderate Mobility Late Successional Associates</th></tr>
<tr><td colspan="2">Representative species: Marten (Martes americana), Fisher (Martes pennanti), Spotted Owl (Strix occidentalis), Flying Squirrel (Glaucomys sabrinus), Brown Creeper (Certhia americana)
• Closed canopy, late successional associates, tree species composition and elevation not considered.
• Model patterned after marten H.S.I. model (Allen 1982) with road and building factors added.</td></tr>
<tr><th>Source Model Parameters</th><th>Dispersal Model Parameters</th></tr>
<tr><td>Canopy Closure (CC)
<30 to 40% = poor (0.1)
30 –50% = mod (0.5) (PMR data only)
>40 or 50% = good (1)
Size Class (SZ)
Non forest = poor (0.1)
Pole/Small = poor (0.1)
Medium = mod (0.7)
Large = good (1)
Road Density (RD)
<4mi/mi^2 = good (1)
4-6 mi/ mi^2 = mod (0.5)
>6 mi/ mi^2 = very poor (0.1)
Building Density (BD)
<10/ mi^2 = good (1)
10-50/ mi^2 = mod (0.5)
>50/ mi^2 = poor(0.1)

<u>Model Form</u>
(CC*SZ*RD*BD) focalsummed to identify blocks of good habitat.
Source areas must be larger than 4mi^2 and have >70% habitat suitability within a 1mi^2 moving window.</td><td>Canopy Closure (CC)
Non forest = poor (0.3)
<10% = mod (0.5)
10-40 or 50% = mod/good (0.75)
>40 or 50% = good (1)
Size Class (SZ)
Non forest = poor (0.3)
Pole/Small = poor/mod (0.5)
Med = mod (0.75)
Large = good (1)
Road Density (RD)
<4mi/ mi^2 = good (1)
4-6 mi/ mi^2 = mod (0.5)
>6 mi/ mi^2 = poor (0.1)
Building Density (BD)
<10/ mi^2 = good (1)
10-50/ mi^2 = mod (0.5)
>50/ mi^2 = poor(0.1)
Slope Class (SL)
<100% = good (1)
>100% = poor (0.1)

<u>Model Form</u>
(CC*SZ*RD*BD*SC*SL)</td></tr>
</table>

Table 3.1 (continued): Representative species, key characteristics, and model parameters for I-90 Snoqualmie Pass Linkage Assessment habitat linkage modeling guilds.

<table>
<tr><th colspan="2">Low Mobility Late Successional Associates</th></tr>
<tr><td colspan="2">Representative species: Trowbridge's Shrew (Sorex trobridgi), Shrew-Mole (Neurotrichus gibbsi), Red-Backed Vole (Clethrionomys gapperi), Oregon Megomphix Land Snail (Megomphix hemphilli), Blue-Grey Tail-dropper (Prophysaon coeruleum), Keeled Jumping Slug (Hemphillia burringtoni).
• Model based on habitat associations described in Brown et al. 1985, I-90 Land Exchange DEIS (USDA Forest Service 1998), and Washington State GAP (Dvornich et al. 1997).
• Road density is not a factor because these species do not perceive the landscape at mi^2 scales, though roads themselves are a barrier to movement. A road grid layer (RG), with the cells containing roads attributed 1, was used to consider the impact of roads on these species. Human disturbance associated with buildings is not a factor.</td></tr>
<tr><th>Source Model Parameters</th><th>Dispersal Model Parameters</th></tr>
<tr><td>Canopy Closure (CC)
>60-70% = good (1)
40-70% = mod (0.75)
<40% = poor (0.5)
Size Class (SZ)
Med-Large = good (1)
Small-Med = mod (0.75)
Open-Small = poor (0.5)
Non forest = very poor (0.1)

<u>Model Form</u>
(CC*SZ) thresholded on minimum polygon size</td><td>Canopy Closure (CC)
>60-70% = good (1)
40-70% = mod (0.75)
<40% = poor (0.5)
Size Class (SZ)
Med-Large = good (1)
Small-Med = mod (0.75)
Open-Small = poor (0.5)
Non forest = very poor (0.1)
Road Grid (RG)
1 = poor (0.5)
0 = good (1)

<u>Model Form</u>
(CC*SZ*RG)</td></tr>
<tr><th colspan="2">Low Mobility Late Successional Riparian Associates</th></tr>
<tr><td colspan="2">Representative species: Tailed Frog (Ascaphus truei), Pacific Water Shrew (Sorex bendirei), Warty Jumping Slug (Hemphillia glandulosa), Puget Oregonian Land Snail (Cryptomastix devia).
• This model identifies closed canopy forest along streams, otherwise it is similar to low mobility late successional species.
• A concern with this model is that riparian patch size may be smaller than the resolution of the TM data</td></tr>
<tr><th>Source Model Parameters</th><th>Dispersal Model Parameters</th></tr>
<tr><td>Canopy Closure (CC)
>60-70% = good (1)
40-70% = mod (0.75)
<40% = poor (0.5)
Size Class (SZ)
Med-Large = good (1)
Small-Med = mod (0.75)
Open-Small = poor (0.5)
Non forest = very poor (0.1)
Distance to water (DW)
<30m = good (1)
>30m = very poor (0.1)

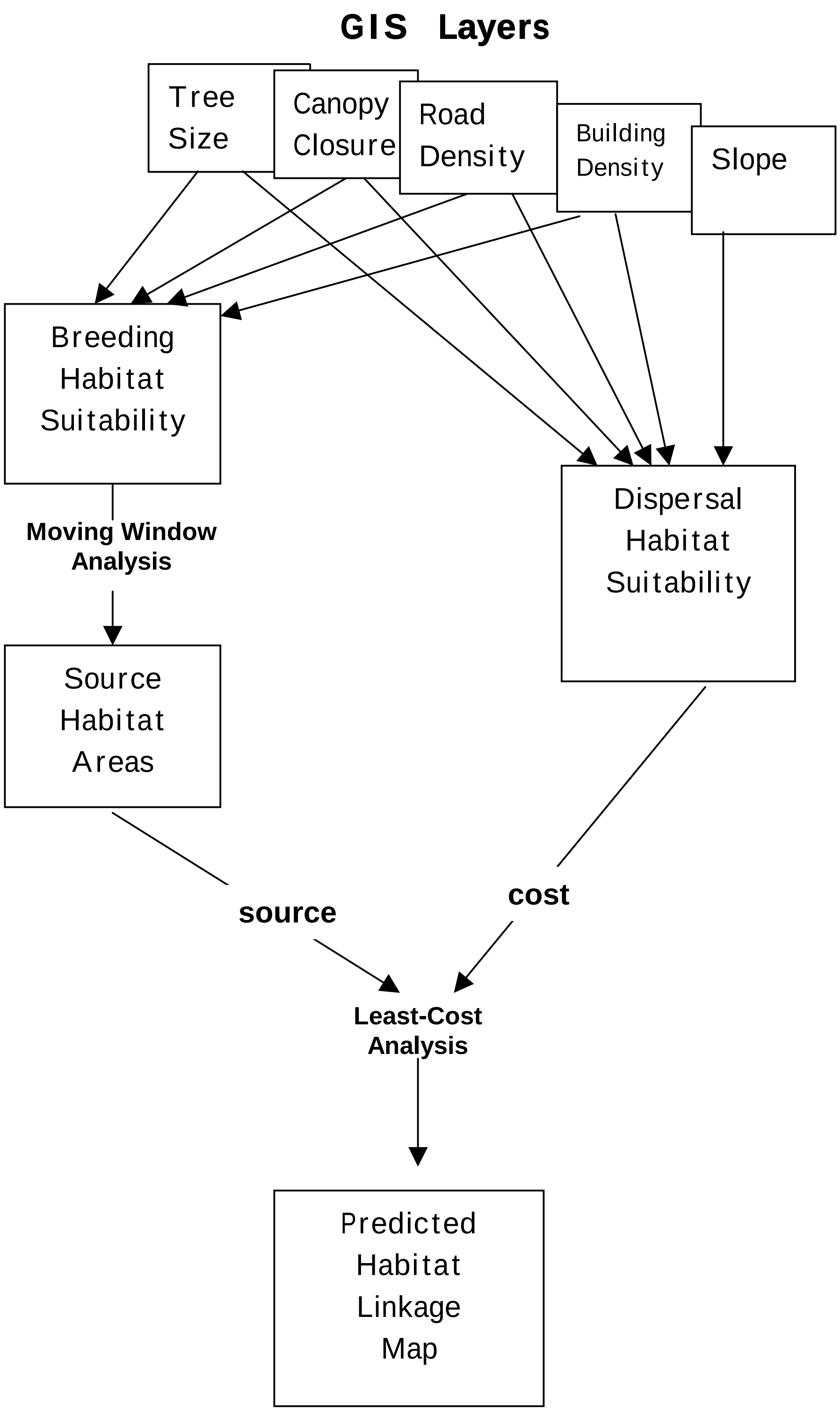
<u>Model Form</u>
(CC*SZ*DW)</td><td>Canopy Closure (CC)
>60-70% = good (1)
40-70% = mod (0.75)
<40% = poor (0.5)
Size Class (SZ)
Med-Large = good (1)
Small-Med = mod (0.75)
Open-Small = poor (0.5)
Non forest = very poor (0.1)
Road Grid
1 = poor (0.5)
0 = good (1)
Distance to water (DW)
<30m = good (1)
30-120m = mod (0.75)
>120m = very poor (0.1)

<u>Model Form</u>
(CC*SZ*RG*DW)</td></tr>
</table>

Table 3.2. GIS landscape data layers used for I-90 Snoqualmie Pass landscape linkage modeling.

Data Layer	Description
Canopy Closure	Two data sets were used; • USFS (PMR) classified landsat imagery, 30m pixel size based on 1992 satellite image • Boise Cascade Co. classified landsat imagery, 30m pixel size based on 1995 satellite image (this image was classified for the Boise Cascade Teanaway Ecosystem Management Project).
Tree Size Class	Two data sets were used; • USFS (PMR) classified landsat imagery, 30m pixel size based on 1992 satellite image • Boise Cascade Co. classified landsat imagery, 30m pixel size based on 1995 satellite image (this image was classified for the Boise Cascade Teanaway Ecosystem Management Project).
Hydrology	USFS Wenatchee National Forest and Mount Baker Snoqualmie National forest corporate data layers, derived from USGS DLG 1:24000 data.
Roads	USFS Wenatchee National Forest and Mount Baker Snoqualmie National forest corporate data layers.
Buildings	USGS Cartographic Feature File, 1:24000 scale, updated from 1995 digital orthophotos.

Figure 3.1. Flow chart of the least-cost path wildlife habitat linkage modeling approach used for the I-90 Snoqualmie Pass Linkage Assessment.



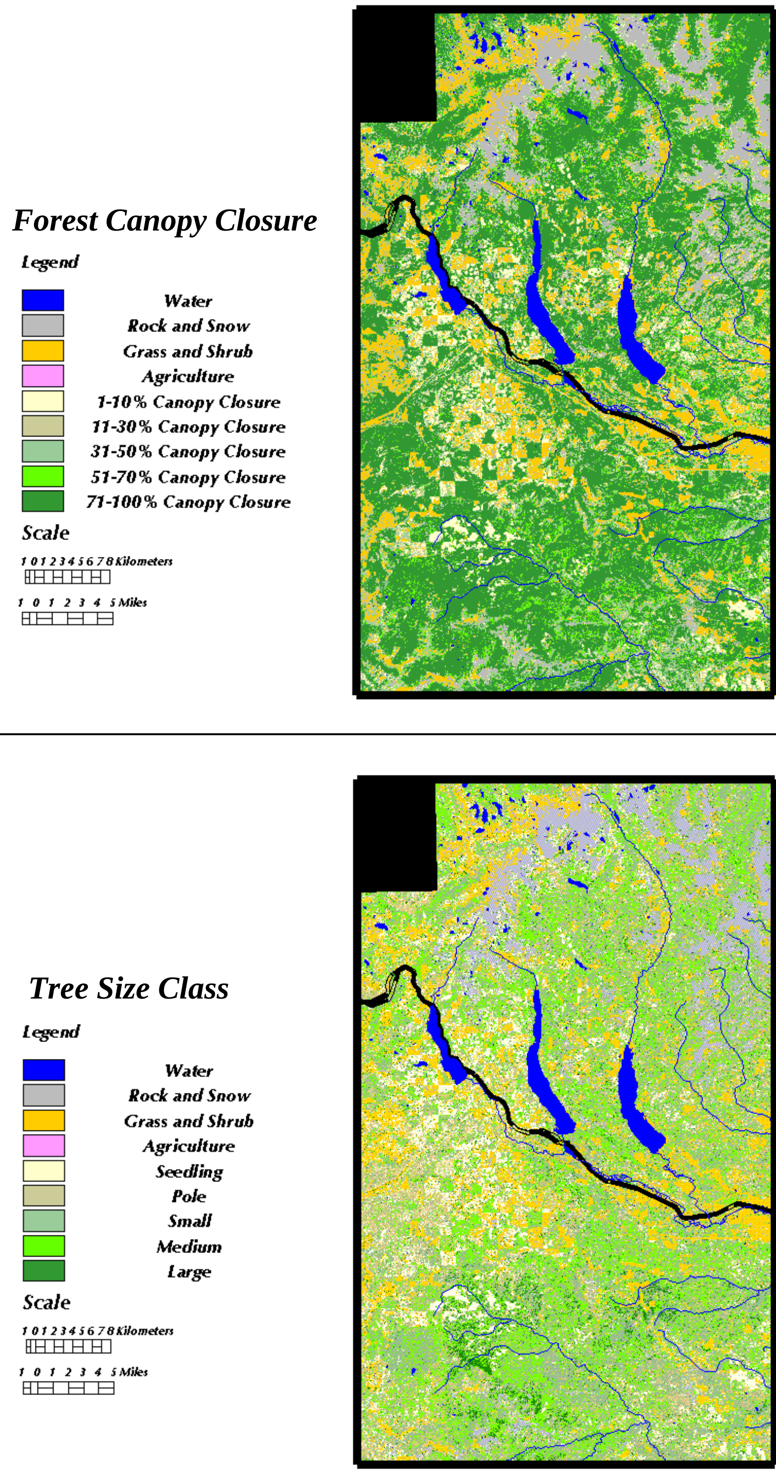


Figure 3.2. I-90 habitat connectivity modeling landscape-scale habitat data maps.

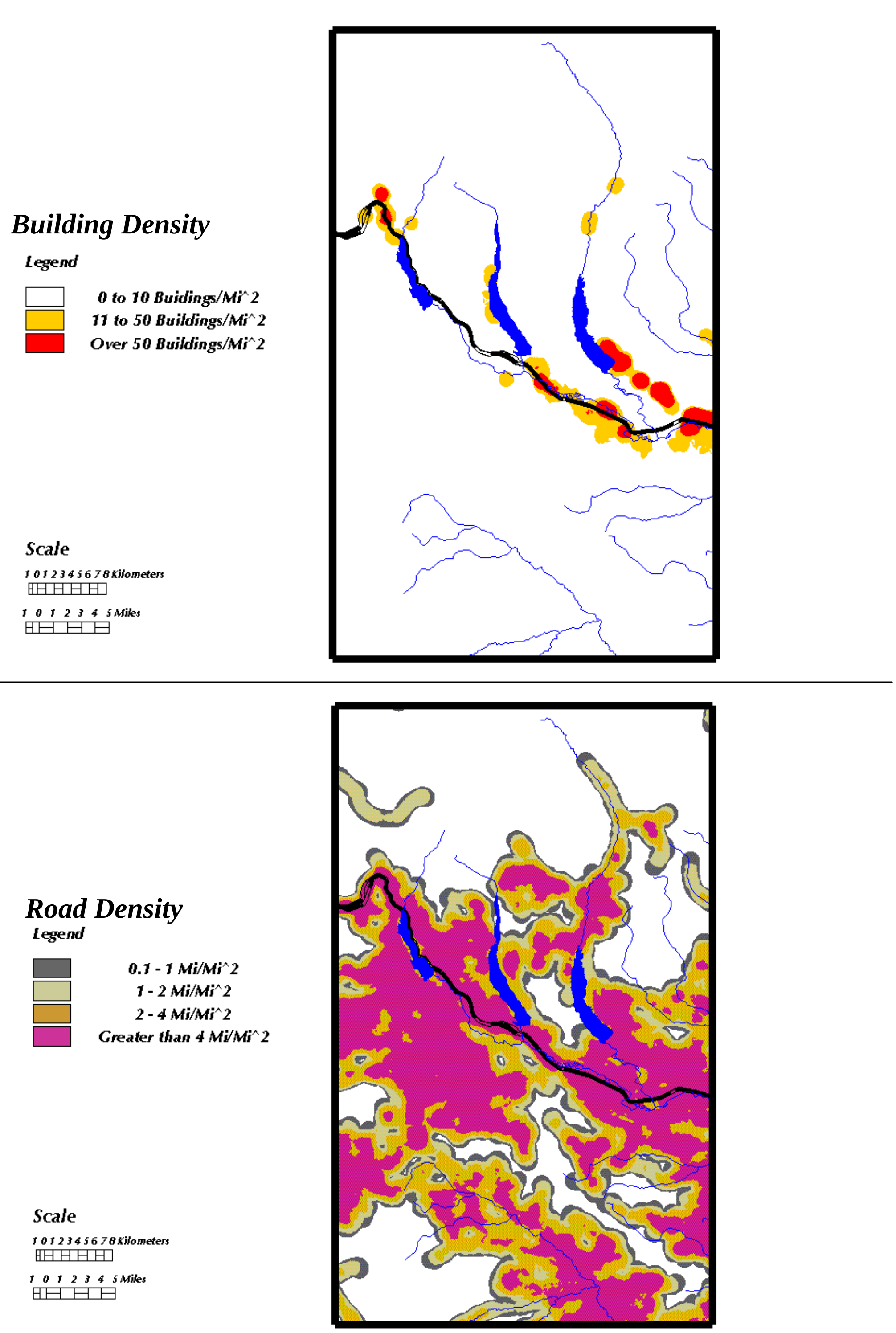


Figure 3.2 (continued). I-90 habitat connectivity modeling landscape-scale habitat data maps.

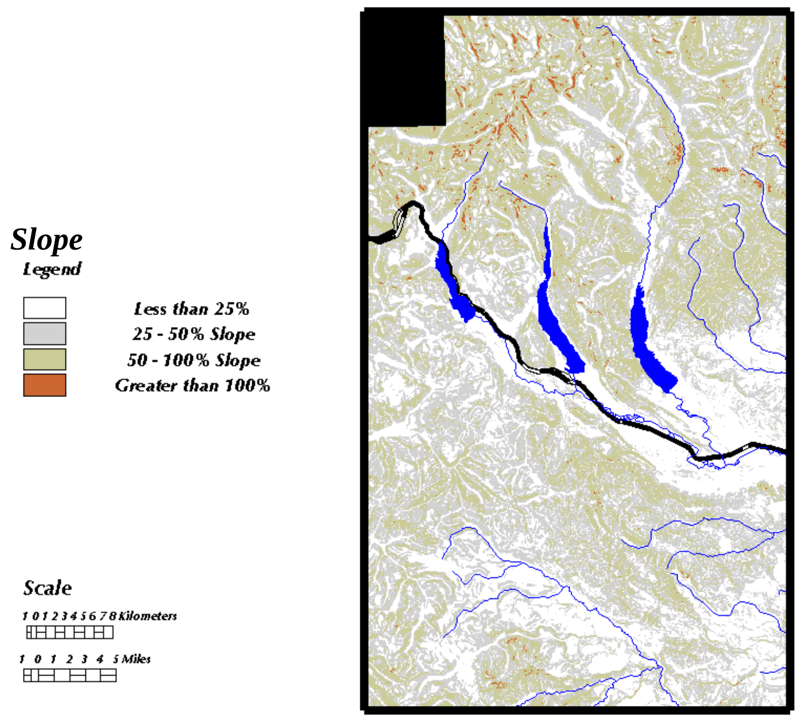


Figure 3.2 (continued). I-90 habitat connectivity modeling landscape-scale habitat data maps.

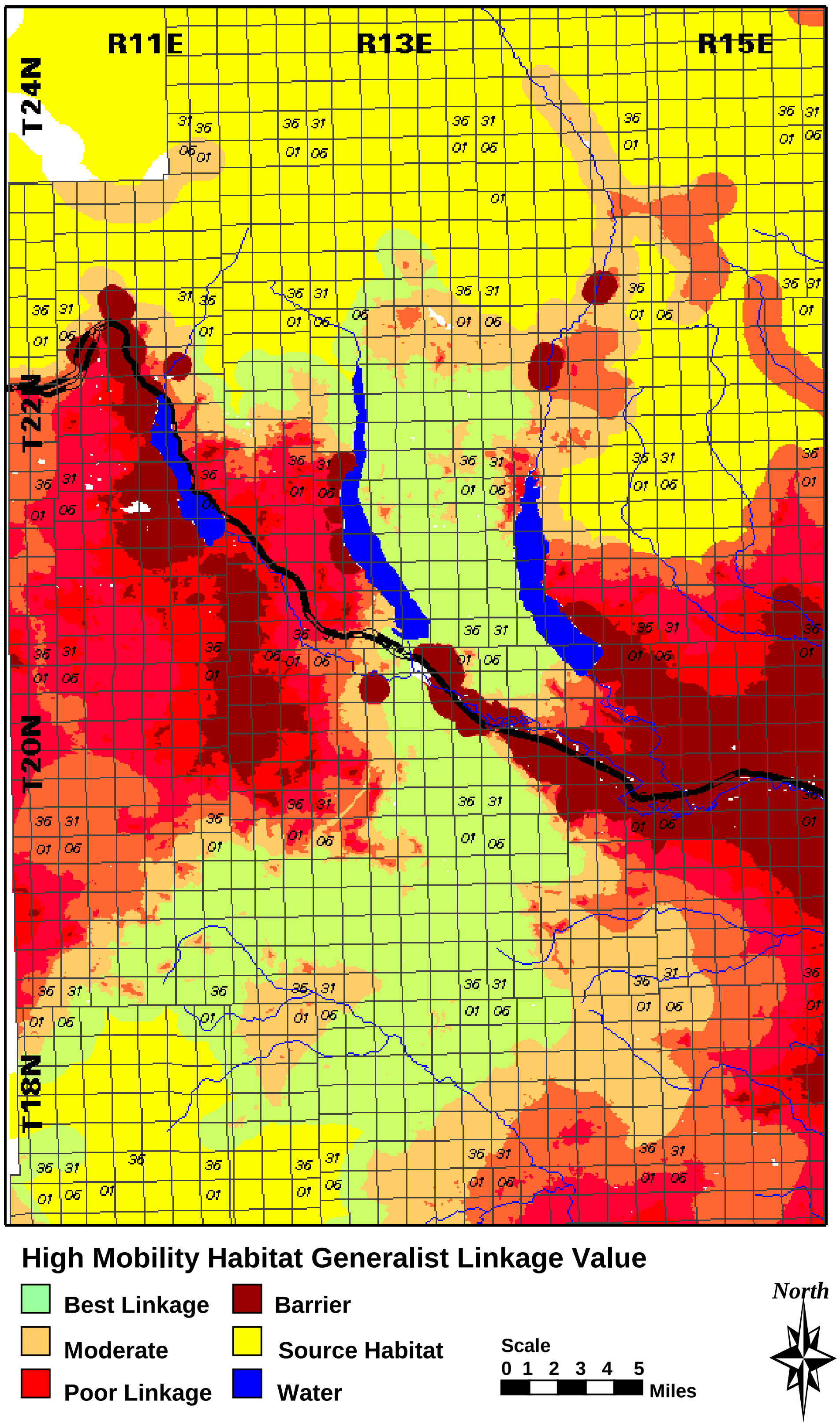


Figure 3.3. I-90 habitat connectivity modeling results for high mobility habitat generalist species.

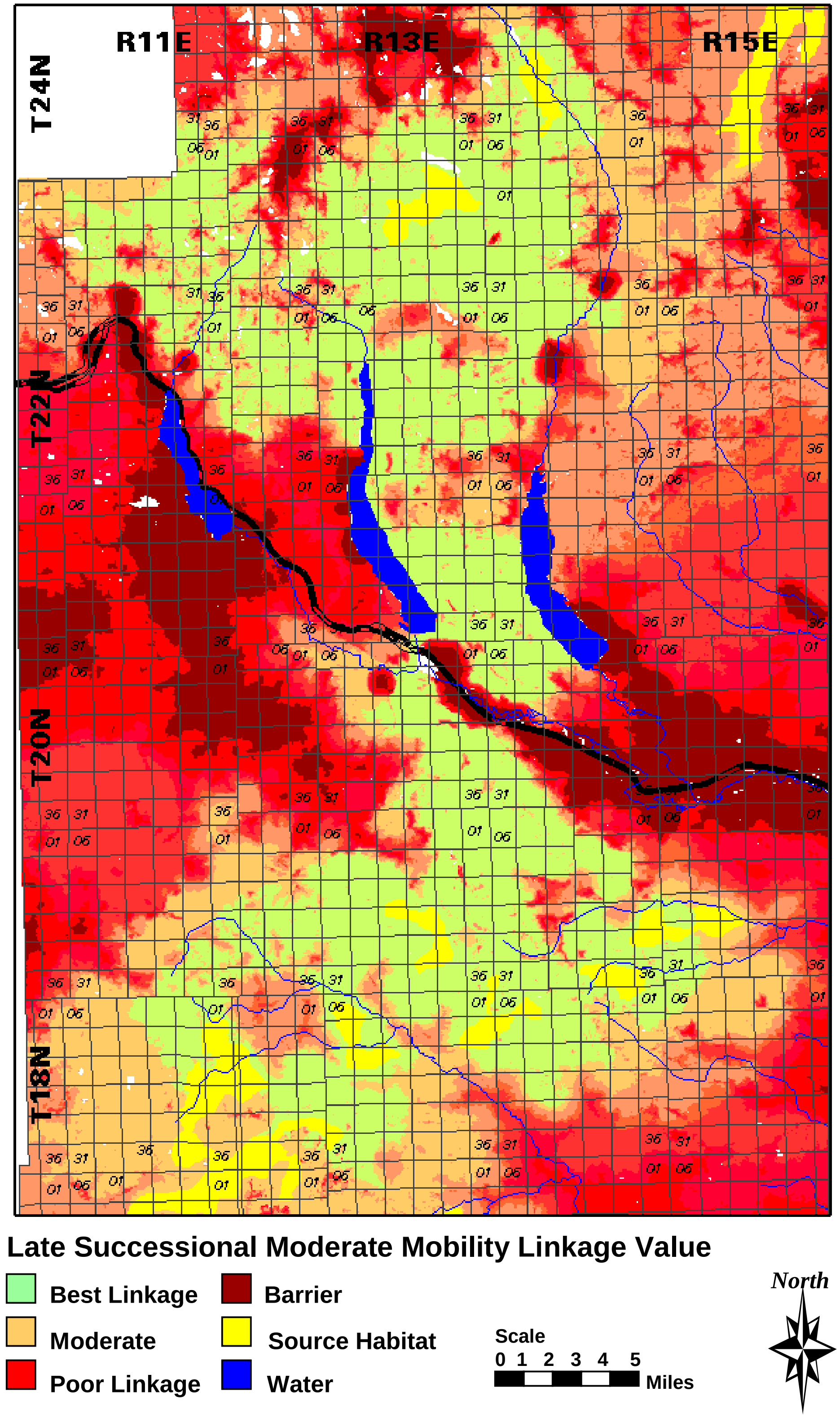


Figure 3.4. I-90 habitat connectivity modeling results for late successional moderate mobility species.

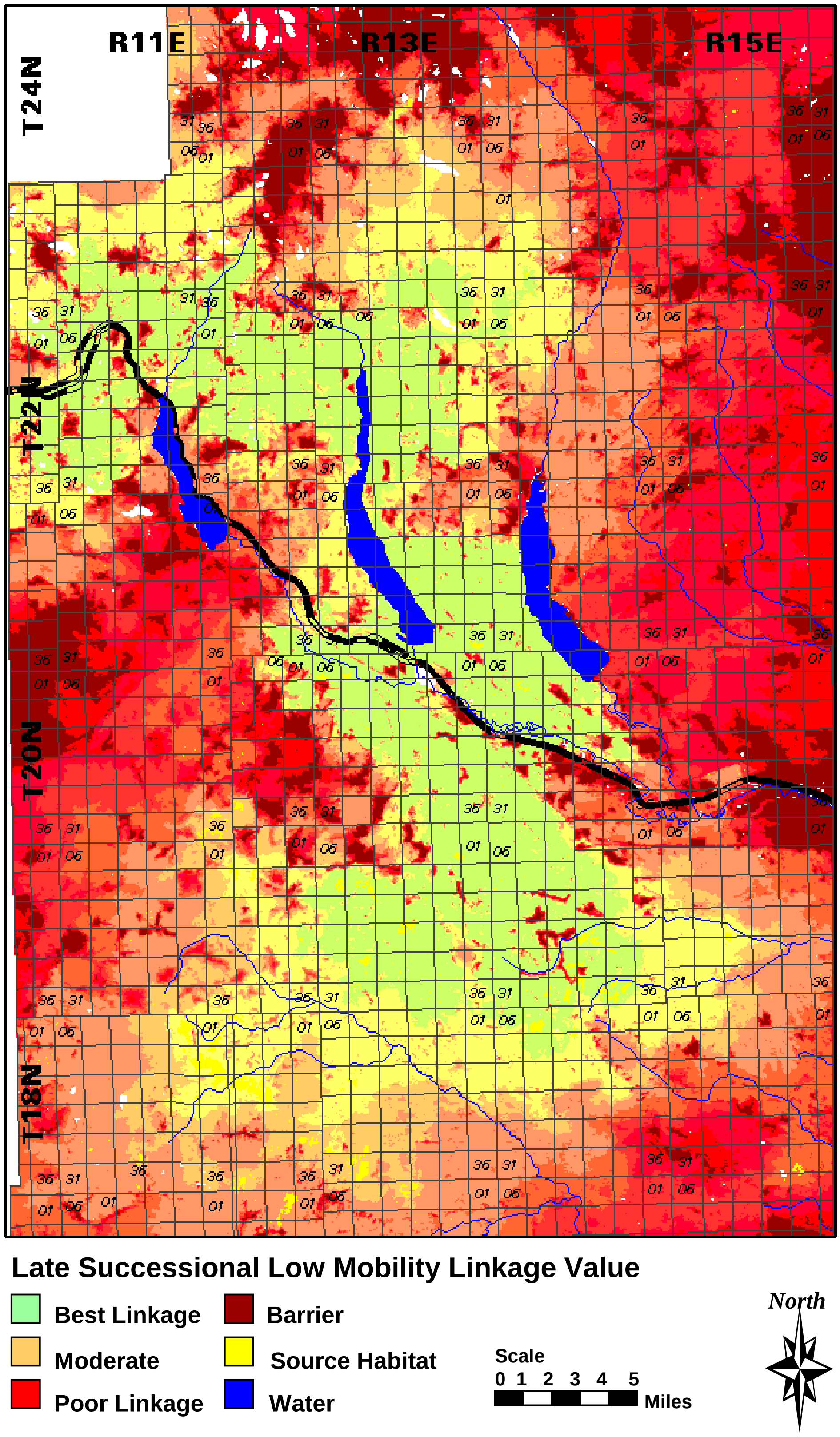


Figure 3.5. I-90 habitat connectivity modeling results for late successional low mobility species.

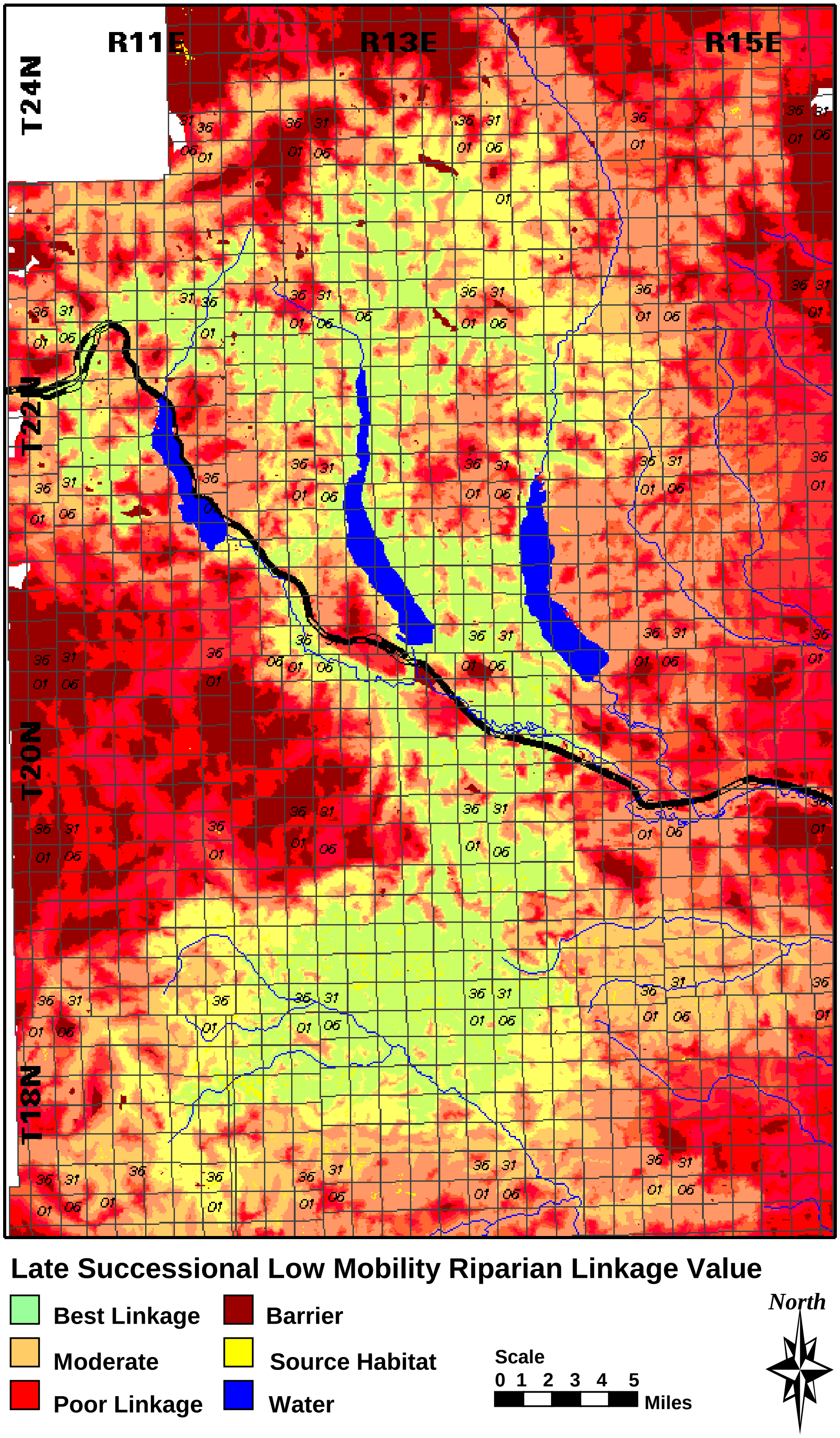


Figure 3.6 I-90 habitat connectivity modeling results for late successional low mobility riparian associate species.

4) Camera Surveys

4.1) Introduction

Our objective in conducting automatic camera surveys and compiling existing camera data was to evaluate the distribution of wildlife, particularly forest carnivores, in the vicinity of I-90 and the adjacent landscape. Camera surveys are a standard technique for wildlife inventory and monitoring (Kucera et al. 1995). We attempt to address 4 questions with the camera survey data: 1) What are the differences in rates of detection and species detected along I-90 compared to areas away from the highway? 2) Where along I-90 are animals distributed? 3) What are the differences between animals detected at camera stations along the highway compared to those animals detected crossing the highway? And, 4) How do animal detection rates at camera stations relate to predicted landscape permeability?

4.2) Methods

From September 1998 to March 2000, we conducted automatic camera surveys in forest habitats less than 1 mile from the highway (figure 4.1). Sampling was stratified by highway section and we attempted to keep at least 1 camera in operation in each highway section during the monitoring periods. TrailMaster automatic camera systems, consisting of an Olympus 35mm camera connected to a passive infrared heat and motion-detecting monitor, were used for these surveys. The stations were baited with deer or elk parts and predator attractant disks. We attempted to maintain camera stations for a minimum of 28 nights, following the protocol suggested by Kucera et al. (1995). Detection nights were counted for each night the unit was operational and the bait was intact.

We also compiled data collected during camera surveys conducted by Mt. Baker – Snoqualmie National Forest, North Bend Ranger District and Wenatchee National Forest, Cle Elum Ranger District personnel from September 1995 to August 1997. These camera stations were located in forested habitats near and east of the Cascade Crest. Stations were located up to 17 miles from I-90 and provide useful information on the broader distribution of wildlife in the central Cascades.

Due to substantial differences in species detected and detection rates between seasons, we classified the camera stations as being winter or summer stations. Winter stations were conducted between November and April. Summer stations were conducted between May and October.

We examined detection rates of each species detected at automatic camera stations relative to distance from the highway by comparing detection rates at stations within 1 mile of I-90 to stations more than 1 mile from I-90. We conducted Fisher's exact tests (using SPSS v9.0) to compare the proportion of stations at which a species was detected relative to distance to the highway. Winter and summer stations were analyzed separately.

Animal distribution along I-90 was assessed by comparing the proportion of camera stations in each highway section at which a species was detected. We conducted binomial

2-sided probability tests (Zar 1999, p 518) to identify highway sections where the detection rate for a species was significantly different from the average detection rate for that species across all highway sections. Winter and summer stations were analyzed separately.

We assessed the relationship of animal detection rates to predicted landscape linkage value by conducting t-tests to compare the average predicted movement cost at stations with detections of the species of concern to the average predicted movement cost at stations with no detections of that species. Winter and summer stations were analyzed separately.

4.3) Results

We compiled data for 132 camera stations (totaling approximately 4095 detection nights) in the vicinity of the I-90 study area (figure 4.1). Fifty-one stations were conducted by Mt. Baker – Snoqualmie National Forest and Wenatchee National Forest personnel between September 1995 and August 1997. Eighty stations were conducted during this project. Eighty-one of the camera stations were located within 1 mile of I-90, including 42 stations conducted during summer and 39 conducted during winter. Twelve of the stations compiled from national forest surveys and 13 of the stations from this project were conducted for less than the 28 night minimum because of personnel limitations, repeated loss of bait, or equipment malfunction.

Nineteen species of mammals (including humans and dogs) were detected during summer camera surveys and 11 species were detected during winter surveys (table 4.1). Mule deer, black bear, Douglas squirrel, chipmunks, and elk were the most commonly detected species during summer surveys. Bobcat, snowshoe hare, and coyote were the most commonly detected species during winter.

Comparison of detection rates for wildlife at camera stations less than 1 mile from the highway to those farther away did not show substantial differences between these areas (table 4.1). Mule deer were the only regularly detected species that showed a significant difference in detection rate relative to distance to the highway ($p = 0.07$). During summer, mule deer were more commonly detected close to the highway. Mule deer were recorded at only 1 station during the winter. Despite relatively low detection rates, statistically significant differences in seasonal detection rates were also identified for domestic dogs (only detected close to the highway in both seasons, but significant only for summer) and American marten (significant for winter stations during which marten were detected only away from the highway, though marten were also detected at 2 stations close to the highway during summer). Differences in detection rates for other species were not statistically significant, though there were some interesting patterns. Small mammal prey species, including Douglas squirrel, snowshoe hare, northern flying squirrel, and chipmunks, were consistently detected more frequently away from the highway. Bobcat and coyote were both detected substantially more frequently within 1 mile of the highway during winter, though summer detection rates near and far from I-90 were very similar.

Notable differences in detection rates between highway sections were found for some species (table 4.2). Bobcats were detected during winter significantly more often along the Easton Hill, Amabalis Mtn., and Snoqualmie Pass sections compared to their average detection rate across all highway sections. Though not statistically significant, bobcat were detected during winter substantially less often in the Yakima Valley compared to other portions of the study area. Coyote were detected during winter in the Easton Hill, Amabalis Mtn., and Keechelus South sections. Coyote were not detected during winter in the Yakima Valley and Snoqualmie Pass sections. Black bear were never detected in the Yakima Valley section, but were frequently detected during summer in the Easton Hill, Amabalis Mtn., and Keechelus South sections. American marten were only detected near the crest of Snoqualmie Pass. Elk and mule deer detections were distributed throughout the study area.

Comparison of detection rates of carnivores and ungulates at camera stations within 1 mile of I-90 to predicted landscape permeability for high mobility habitat generalist species did not show strong evidence of increased detection rates at stations with lower predicted movement cost for most regularly detected species (table 4.3). Bobcat winter detections were the only group of detections for which average predicted movement cost was significantly (t-test $p = 0.01$) lower at stations where detections were recorded compared to stations without detections. Average predicted movement cost was also lower for winter stations with coyote detections and summer stations with black bear detections, though the statistical evidence of these differences is not strong (t-test $p = 0.30$ for coyote and $p = 0.59$ for bear). Predicted movement costs were generally, but not significantly, higher at summer stations with detections of all analyzed species except black bear (these species include human, coyote, bobcat, elk, and mule deer).

Species of wild mammals detected at camera stations more than 1 mile from the highway but not closer were porcupine, mountain lion, bushy-tailed woodrat, and weasel (table 4.1). Porcupine, weasel, and bushy-tailed woodrat were detected during snow tracking or highway structure monitoring along the highway, so the lack of camera detections of these species does not indicate their absence from the study area. Mammal species detected during automatic camera surveys, but not detected approaching or crossing the highway during highway structure monitoring or snow tracking were mountain lion and black bear.

Mountain lions were detected at 2 stations 10.5 and 14.3 miles from the highway. No mountain lions were recorded during surveys along I-90, however mountain lion tracks were documented on June 16, 1999 while accessing camera station 9920, approximately 0.5 mile southwest of milepost 63. A road-killed mountain lion was also documented in this area (milepost 62) on October 15, 1999. Anecdotal reports of mountain lions in the vicinity of Rosyln and Easton are not uncommon. These few detections of mountain lions may indicate that this species is present in the study area at a relatively low density or is not responsive to baited camera stations near the highway.

A large canid that could have been a gray wolf was detected in the vicinity of Box Canyon, northwest of Kachess Lake at a camera station conducted by Wenatchee National Forest, Cle Elum Ranger District personnel in 1997 (Wenatchee National Forest, Cle Elum Ranger District wildlife records). Reports of wolf-like howling were also documented a few miles away in the spring of 1997. We are not aware of any more recent reports of possible wolf activity in that area.

Wolverine and lynx have not been detected during camera surveys compiled here. However, hair-sampling surveys conducted in 1998 indicated potential lynx presence north and south of I-90. Wolverine tracks were also documented on Amabilis Mtn., approximately 1 mile north of I-90, in March 1998 while members of the snow tracking field crew from this project were recreationally skiing in the area.

Table 4.1. Seasonal detection rates of wildlife species documented at automatic camera stations greater and less than 1 mile from I-90. Summer stations were conducted from May to October. Winter stations were conducted from November to April. The upper number indicates the number of stations where the species was detected. The lower number indicates the percentage of stations in that category at which the species was detected (the detection rate). Detection rates which have a 90% or greater probability (based on Fisher's exact test 2-sided significance) of being different based on distance to the highway are indicated in bold.

	Summer				**Winter**			
Species	**>1 mile (n = 24)**	**<1 mile (n = 42)**	**Total (n = 66)**	**P***	**>1 mile (n = 27)**	**<1 mile (n = 39)**	**Total (n = 66)**	**P***
Mule Deer	**7 29%**	**23 55%**	**30 45%**	**0.07**	1 4%	0 0%	1 2%	0.41
Douglas Squirrel	9 37%	12 29%	21 32%	0.58	5 18%	2 5%	7 11%	0.19
Bobcat	2 8%	2 5%	4 6%	0.62	10 37%	22 56%	32 48%	0.14
Black Bear	8 33%	14 33%	22 33%	1.00				
Snowshoe Hare	6 25%	8 19%	14 21%	0.75	5 18%	5 13%	10 15%	0.73
Elk	3 12%	16 38%	19 29%	0.24	1 4%	0 0%	1 2%	0.41
Northern Flying Squirrel	7 29%	10 24%	17 26%	0.77	2 7%	1 3%	3 5%	0.56
Coyote	4 17%	5 12%	9 14%	0.71	2 7%	6 15%	8 12%	0.45
Dog	**0 0%**	**6 14%**	**6 9%**	**0.08**	0 0%	4 10%	4 6%	0.14
American Marten	0 0%	2 5%	2 3%	0.53	**4 15%**	**0 0%**	**4 6%**	**0.02**
Human	0 0%	5 12%	5 8%	0.15				
Chipmunks	9 37%	12 29%	21 32%	0.58				
Stripped Skunk	0 0%	2 5%	2 3%	0.53	1 4%	2 5%	3 5%	1.00
Mountain Lion	2 8%	0 0%	2 3%	0.13				
Weasel	1 4%	0 0%	1 2%	0.36	1 4%	0 0%	1 2%	0.41
Porcupine	1 4%	0 0%	1 2%	0.36				
Bushy-tailed Woodrat	1 4%	0 0%	1 2%	0.36				
Spotted Skunk	0 0%	1 2%	1 2%	0.64				
Beechey Ground Squirrel	0 0%	1 2%	1 2%	0.64				

*Fisher's exact test 2-sided significance (the probability that, given a very large sample size, detection rates for the indicated species and season would be equal for stations greater or less than 1 mile from the highway).

Table 4.2. Seasonal detection rates, by highway section, for wildlife species documented at automatic camera stations along interstate 90. Cells that have a 90% or higher probability (based on binomial test 2-sided significance) of having higher or lower detection rates than the average detection rate across all highway sections for that season are indicated in bold. Summer stations were conducted from May to October. Winter stations were conducted from November to April.

Species		Summer						Winter					
		1) Yakima Valley (n = 8)	2) Easton Hill (n = 9)	3) Amabalis Mtn. (n = 7)	4) Keechelus South (n = 8)	5) Snoqualmie Pass (n = 10)	Total (n = 42)	1) Yakima Valley (n = 4)	2) Easton Hill (n = 8)	3) Amabalis Mtn. (n = 4)	4) Keechelus South (n = 10)	5) Snoqualmie Pass (n = 13)	Total (n = 39)
Mule Deer	No.[1]	5	5	3	4	6	23						
	Pct.[2]	63%	56%	43%	50%	60%	55%						
	P[3]	0.26	0.26	0.24	0.26	0.24							
Elk	No.	5	2	2	4	3	16						
	Pct.	63%	22%	29%	50%	30%	38%						
	P	0.11	0.18	0.28	0.22	0.23							
Bobcat	No.	1	0	1	0	0	2	1	**7**	**4**	5	**5**	22
	Pct.	13%	0%	14%	0%	0%	5%	25%	**88%**	**100%**	50%	**38%**	56%
	P	0.27	0.64	0.25	0.68	0.61		0.19	**0.06**	**0.10**	0.23	**0.10**	
Black Bear	No.	**0**	4	4	3	3	14						
	Pct.	**0%**	44%	57%	38%	30%	33%						
	P	**0.04**	0.20	0.13	0.27	0.26							
Douglas Squirrel	No.	4	3	2	3	**0**	12	0	0	0	1	1	2
	Pct.	50%	33%	29%	38%	**0%**	29%	0%	0%	0%	10%	8%	5%
	P	0.12	0.26	0.32	0.24	**0.03**		0.81	0.66	0.81	0.32	0.35	
Northern Flying Squirrel	No.	0	3	2	2	3	10	**1**	0	0	0	0	1
	Pct.	0%	33%	29%	25%	30%	24%	**25%**	0%	0%	0%	0%	3%
	P	0.11	0.22	0.31	0.31	0.24		**0.09**	0.81	0.90	0.77	0.70	
Snowshoe Hare	No.	1	2	**3**	2	0	8	0	1	0	**3**	1	5
	Pct.	13%	22%	**43%**	25%	0%	19%	0%	13%	0%	**30%**	8%	13%
	P	0.35	0.30	**0.10**	0.29	0.12		0.58	0.39	0.58	**0.10**	0.32	
Coyote	No.	1	0	1	2	1	5	0	2	**2**	2	0	6
	Pct.	13%	0%	14%	25%	10%	12%	0%	25%	**50%**	20%	0%	15%
	P	0.39	0.32	0.39	0.18	0.38		0.51	0.24	**0.10**	0.28	0.11	
Dog	No.	1	**4**	0	0	1	6	0	2	1	1	4	8
	Pct.	13%	**44%**	0%	0%	10%	14%	0%	25%	25%	10%	31%	21%
	P	0.39	**0.02**	0.34	0.29	0.36		0.40	0.30	0.41	0.26	0.16	
Human	No.	1	0	1	2	1	5						
	Pct.	13%	0%	14%	25%	10%	12%						
	P	0.39	0.32	0.39	0.19	0.38							
Stripped Skunk	No.	1	1	0	0	0	2	**2**	0	0	0	0	2
	Pct.	13%	11%	0%	0%	0%	5%	**50%**	0%	0%	0%	0%	5%
	P	0.27	0.29	0.71	0.68	0.61		**0.01**	0.66	0.81	0.59	0.50	
American Marten	No.	0	0	0	0	**2**	2						
	Pct.	0%	0%	0%	0%	**20%**	5%						
	P	0.68	0.64	0.71	0.68	**0.07**							
Spotted Skunk	No.	0	0	0	0	1	1						
	Pct.	0%	0%	0%	0%	10%	2%						
	P	0.82	0.81	0.84	0.82	0.19							
Beechey Ground Squirrel	No.	1	0	0	0	0	1						
	Pct.	13%	0%	0%	0%	0%	2%						
	P	0.16	0.81	0.84	0.82	0.79							

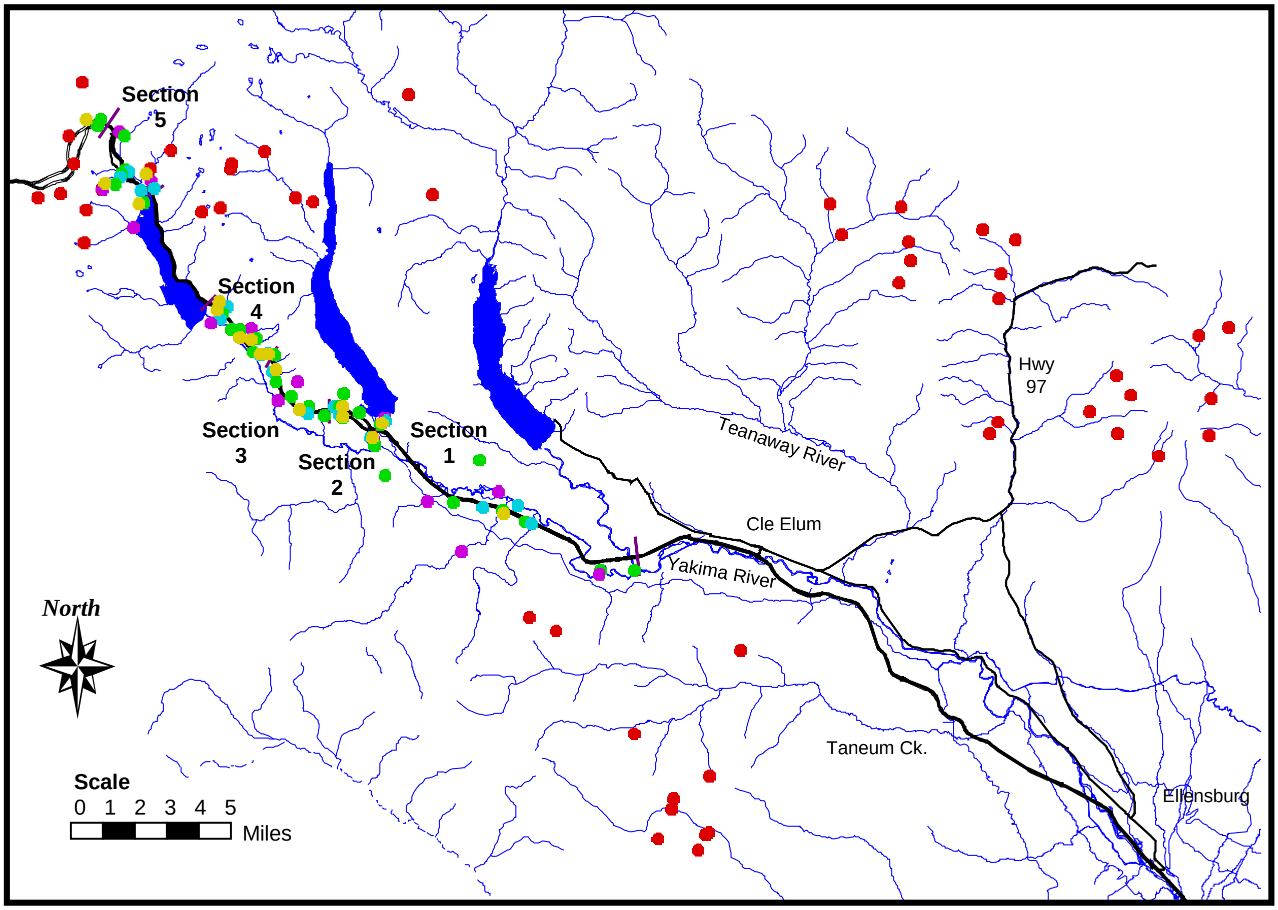
[1]Number of stations where the species was detected.
[2]Percent of stations where the species was detected (detection rate).
[3]Binomial test 2-sided probability (the probability that, given a very large sample size, the detection rate of that species in that section would be equal to our observed average detection rate for the species across all sections).

Table 4.3. Animal detection rates at automatic camera stations within 1 mile of I-90 in relation to predicted landscape permeability from least cost path modeling for high mobility habitat generalist species. Areas with higher relative movement cost are predicted to be less permeable to animal movement. Summer stations were conducted from May to October. Winter stations were conducted from November to April. Statistical analysis was conducted only for seasons during which the indicated species was detected. Analysis of year-round detection rates was not conducted if a species was detected during only one season.

	Relative Movement Cost[1]						Comparison of Means[2]				
	1	**3**	**6**	**8**	**9**	**10**	**Used**	**S.E. (Used)**	**Unused**	**S.E. (Unused)**	**T-test**
	All Stations										
No. Stations	10	7	9	18	13	24					
Coyote	10%	14%	22%	22%	15%	4%	6.9	0.4	7.3	0.8	0.68
Elk	20%	0%	22%	11%	23%	29%	Not Calculated				
Human	0%	0%	0%	11%	8%	8%	Not Calculated				
Bobcat	40%	29%	56%	39%	15%	17%	6.4	0.6	7.6	0.4	0.13
Mule Deer	20%	43%	22%	17%	31%	38%	Not Calculated				
Black Bear	10%	43%	11%	17%	23%	13%	Not Calculated				
	Summer Stations										
No. Stations	6	3	4	8	6	15					
Coyote	0%	0%	25%	25%	17%	7%	8.2	0.7	7.2	0.6	0.27
Elk	33%	0%	50%	25%	50%	47%	7.9	0.8	6.9	0.7	0.32
Human	0%	0%	0%	25%	17%	13%	9.0	0.4	7.1	0.6	0.14
Bobcat	0%	0%	0%	13%	0%	7%	9.0	1.0	7.2	0.5	0.28
Mule Deer	33%	100%	50%	38%	67%	60%	7.5	0.6	7.1	0.8	0.65
Black Bear	17%	100%	25%	38%	50%	20%	6.9	0.8	7.5	0.6	0.59
	Winter Stations										
No. Stations	4	4	5	10	7	9					
Coyote	25%	25%	20%	20%	14%	0%	5.8	1.3	7.4	0.5	0.30
Elk	0%	0%	0%	0%	0%	0%	Not Calculated				
Human	0%	0%	0%	0%	0%	0%	Not Calculated				
Bobcat	100%	50%	100%	60%	29%	33%	6.2	0.7	8.7	0.5	0.01
Mule Deer	0%	0%	0%	0%	0%	0%	Not Calculated				
Black Bear	0%	0%	0%	0%	0%	0%	Not Calculated				

[1]Relative movement cost was calculated by grouping the linkage modeling study area into 10 classes of equal area based on landscape permeability modeled using USFS PMR vegetation data. Areas with movement cost = 1 were predicted to be the most permeable 10% of the landscape. Areas with movement cost = 10 were predicted to be the least permeable.

[2]Used stations were stations with 1 or more detections of the indicated species. Unused stations did not have detections for the indicated species. T-test significance levels are for 2-tailed, equal variances not assumed, tests comparing average movement cost at used and unused stations.



Automatic Camera Station Locations

Legend

- **Winter 2000**
- **Summer 1999**
- **Winter 1999**
- **Summer 1998**
- **National Forest Stations 1995 to 1997**
- **Roads**
- **Highway Sections**

Figure 4.1. Automatic camera station locations for surveys conducted during the I-90 Snoqualmie Pass wildlife habitat linkage assessment, and surveys conducted by the Mount Baker-Snoqualmie and Wenatchee National Forests. Eighty-one automatic camera stations were conducted along I-90 from September 1998 to March 2000, and data for 51 camera stations was compiled from national forest data.

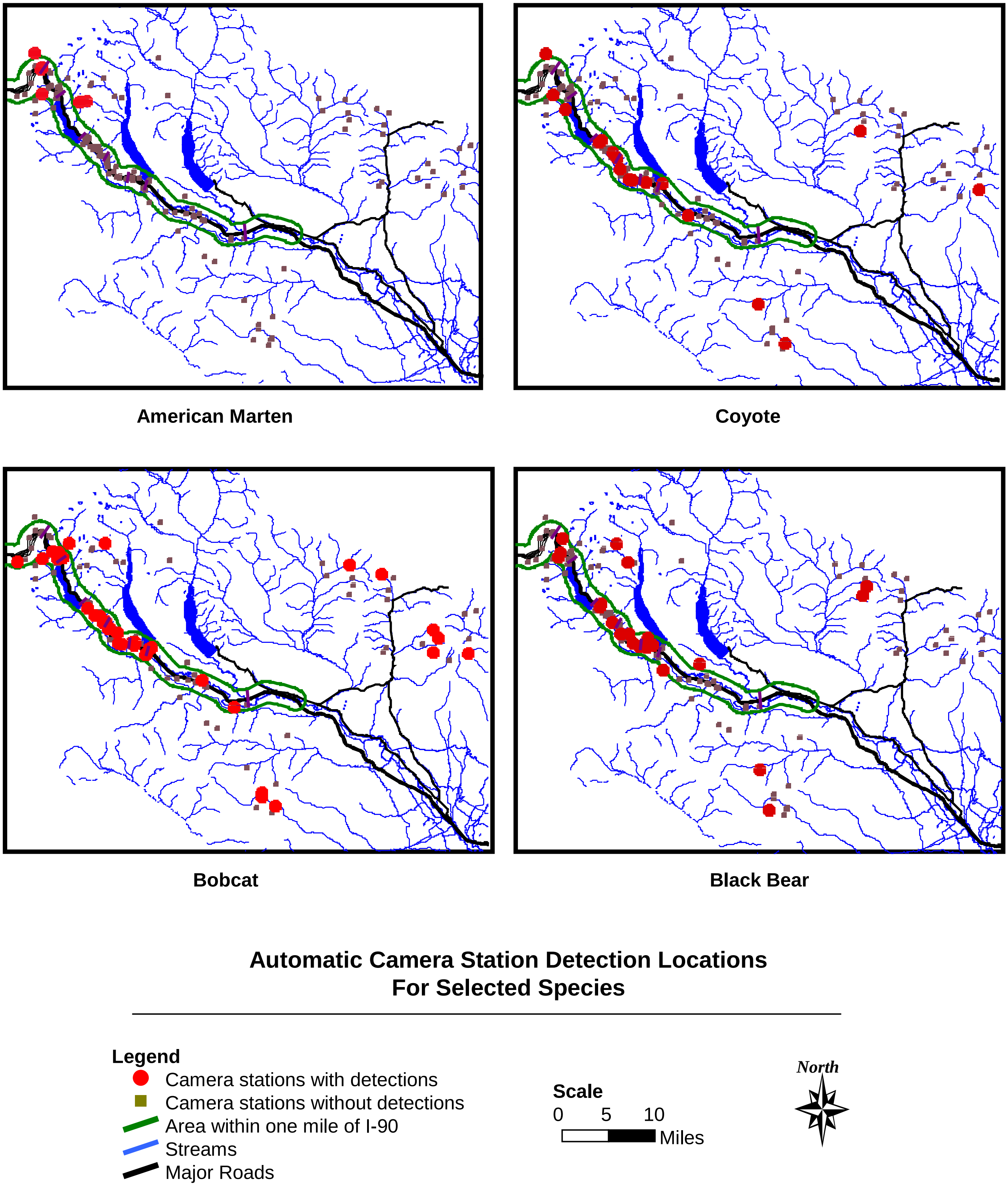
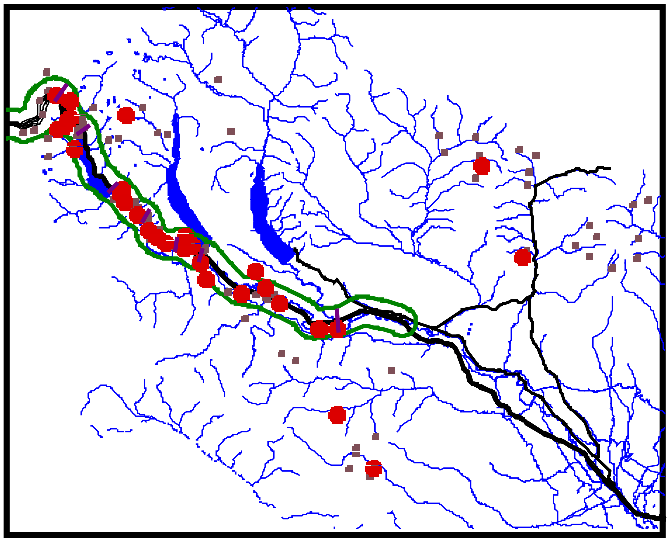
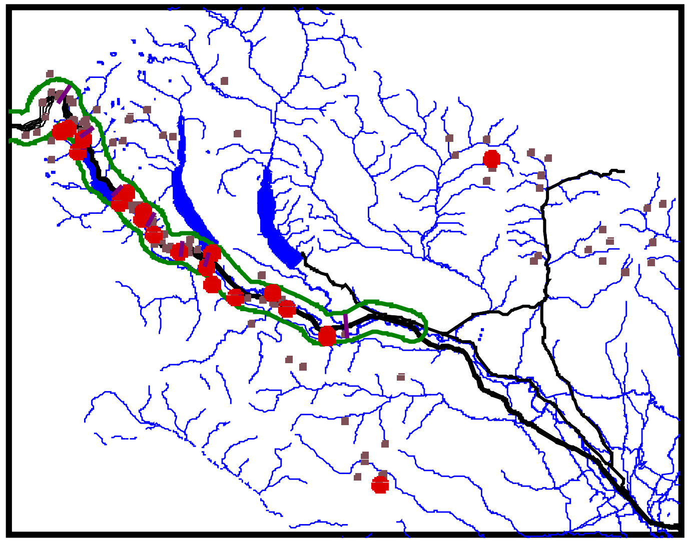


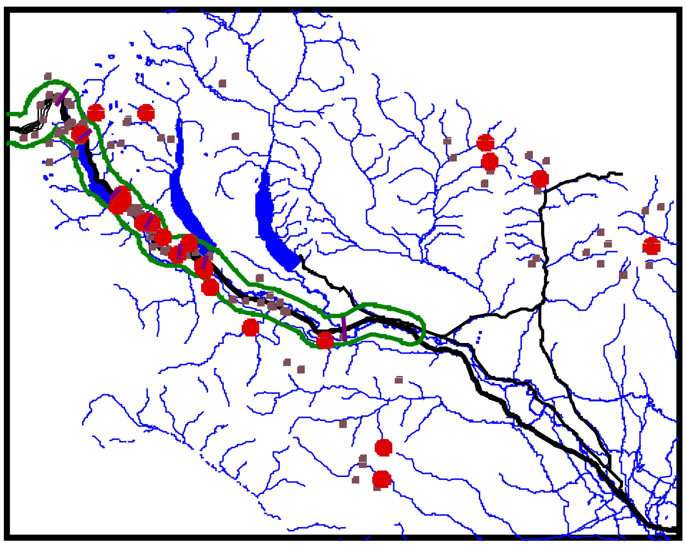
Figure 4.2. Automatic camera station detection locations for selected species in the I-90 study area.



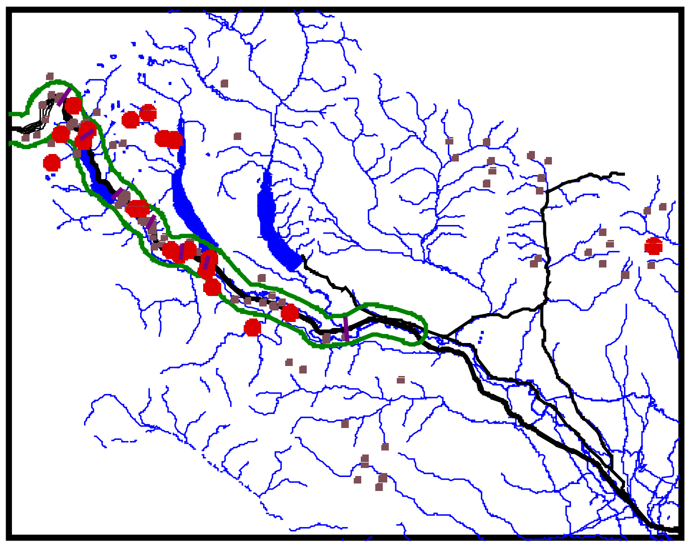
Mule Deer



Elk



Snowshoe Hare



Northern Flying Squirrel

Automatic Camera Station Detection Locations
For Selected Species

Legend
- Camera stations with detections
- Camera stations without detections
- Area within one mile of I-90
- Streams
- Major Roads

Scale
0 5 10
Miles

North

Figure 4.2 (continued). Automatic camera station detection locations for selected species in the I-90 study area.

5) Deer and Elk Road-kill Distribution

5.1) Introduction

We analyzed the distribution of deer and elk road-kills along I-90 to identify where animal entry onto the highway constitutes a human safety concern and where animals regularly attempt to cross the highway. Road-kill locations represent unsuccessful crossing attempts (the animal was killed while trying to cross the highway). We expect that areas with high road-kill frequency are areas of existing or potential habitat connectivity for ungulates.

5.2) Methods

Data on ungulate road-kill locations was collected from 1990 to 1998 (data for 1998 is incomplete). WSDOT maintenance personnel recorded species, date, and location for carcasses removed from the highway during this period. Location was generally recorded to the nearest milepost resulting in a location accuracy of less than or equal to 0.5 miles.

We imported records of species and location of road-kills into the GIS. Map coverages of landscape-scale habitat characteristics were compiled in the GIS (table 5.1) and compared to the road-kill locations. Habitat characteristics were averaged or otherwise generalized to a 1 mile or 1 square mile resolution to match the resolution of the road-kill data. We conducted t-tests (using SPSS ver. 9) for univariate comparisons of ungulate road-kill locations to overall available habitat along the highway. Available habitat was estimated from 2099 points derived from the GIS raster coverage 30 meter cells along the highway.

We also mapped road-kill density by using a 'moving window' analysis to determine the number of kills per mile along I-90. We classified highway segments as high, moderate, or low deer or elk road-kill density by reviewing a graph of road-kills per mile and identifying the levels which distinguished the peaks, plateaus, and valleys in kill frequency for each species. Classification tree analysis was used (using S-Plus 2000) to identify the important landscape characteristics predicting high, moderate, or low road-kill density for deer and elk. Classification tree techniques were chosen for this analysis because they are well suited for analysis of GIS spatial data. Because this is a non-parametric technique, it involves no assumptions of normal distribution, it deals well with categorical data, and it is robust to the relatively subjectively determined sample sizes inherent with GIS raster data.

To evaluate the relationship between ungulate road-kill density and predicted landscape permeability for high mobility habitat generalist species (see chapter 3), we conducted linear regression analysis (using SPSS ver. 9) of deer and elk road-kill density in relation to predicted landscape permeability at the 38 mileposts in the modeling study area. We chose the mileposts as sample points for the regression analysis because most of the road-kill locations were recorded to the nearest milepost.

5.3) Results

We mapped road-kill distribution along 54 miles of I-90 from milepost 35 to milepost 89. Four hundred and ninety deer kill locations and 194 elk kill locations were mapped.

Average yearly kill rates along this section were 54 deer and 23 elk, or approximately 1 deer and one half elk per mile (figure 5.1). Many of the mapped road-kill locations were outside of the Snoqualmie Pass Linkage Assessment study area and therefore were not covered by GIS habitat data compiled for this study. Three hundred and forty-five deer kill locations and 102 elk kill locations were within the study area and were analyzed for correspondence to habitat and roadway characteristics.

Road-kill events show both spatial and temporal patterns. Monthly kill rates of deer show a strong peak in June and July (figure 5.2). Elk kill rates peak in April, with a secondary peak in October. There were also differences between deer and elk in the spatial distribution of kill locations (figures 5.3, 5.4, and 5.6) as well as seasonal changes in the distribution of road-kills (figures 5.5 and 5.7).

Four road-kill concentration areas were identified in the I-90 Snoqualmie Pass study area (figure 5.3). Road-kill concentration areas are located at the north end of Keechelus Lake (mileposts 55 – 57), the south end of Keechelus Lake (mileposts 60 – 63), Easton Hill (mileposts 67 – 69), and along the Cle Elum River at Bullfrog (mileposts 80 – 82). On a broad scale, road-kill distribution appears to be driven largely by landforms that channel animal movement (e.g. lakes, rivers, and mountains), and by human development and disturbance.

The north end of Keechelus Lake has a lower kill rate than the other concentration areas, but kill rates are high here compared to the rest of the highway in the vicinity of the summit of Snoqualmie Pass. Animals hit on the highway in this area are probably moving between the Gold Creek valley, the west side of Keechelus Lake, and the seasonally de-watered portions of the lake bed. Animals appear to be channeled into this area by the rugged topography on either side of Gold Creek, Lake Keechelus, and the combination of dense human development associated with the Snoqualmie Pass ski areas and the small but rugged Cole Creek gully. Collisions with deer occurred in this area during all seasons except winter, and collisions with elk occurred during spring and fall.

The area just south of Keechelus Lake has the second highest concentration of ungulate road-kills in the study area. Animals appear to be channeled into this area by the gentle topography of the Swamp Lake valley, the relatively secure patch of forest just southeast of Keechelus Lake, and human disturbance associated with the Crystal Springs Campground and forest roads 54 (the Stampede Pass road) and 49 (the Kachess Lake road). In this area, collisions with elk occurred during all seasons, while collisions with deer occurred during spring, summer, and fall.

Easton Hill had the highest concentration of elk collisions in the study area. The wide, forested median in this area creates a relatively permeable highway configuration. Amabalis Mountain, Kachess Lake, and the relative security from human disturbance in the surrounding habitat also may channel animals into this area. Human activity and development starting at Easton State Park and continuing east along the Yakima River valley bottom may be shifting north-south movements of animals sensitive to human disturbance, including elk, to the Easton Hill area. This area was identified as the best-connected habitat linkage for old forest species in the landscape modeling component of this study. Collisions with elk in this area occurred during all seasons. Deer were hit in this area during all seasons except winter.

The Cle Elum River area had the highest overall road-kill density in the study area, and had a substantially higher rate of collisions with deer than other areas. Few elk were hit in this area. Collisions with deer occurred during all seasons, though the majority of collisions occurred during the summer. Animals are expected to be channeled into this area by the contiguous forest cover along the river and the relative security from human disturbance provided by the lands north of the highway under the ownership of TrendWest and south of the highway associated with Iron Horse State Park.

Habitat and roadway characteristics of deer and elk kill locations differed between species and differed from overall available habitat (table 5.2 and 5.3). Deer were hit in areas that were significantly (t-test, $p < 0.07$) lower percent cover, gentler slope, narrower paved roadway width, and at lower elevations than available in the study area. Deer were also hit more often than expected in wide valley bottoms and areas with grassy medians (Chi-square $p < 0.001$, df = 2). Deer road-kills occurred less often than expected on hillsides and in areas with Jersey barriers in the median (Chi-square $p < 0.001$, df = 2). Elk kills were recorded in areas that were significantly (t-test, $p < 0.05$) closer to cover, higher percent cover, lower building density, and wider median width compared to available habitat. Elk road-kill locations occurred more often than expected in areas with grassy or forested medians, and less often than expected in areas with jersey barriers in the median (Chi-square $p < 0.001$, df = 2).

Classification tree analysis of elk road-kill density indicates that high density areas are generally characterized by medians wider than 29 feet and building density less than 38 buildings per square mile (figure 5.8). Low density elk road-kill areas are generally characterized by median widths less than 29 feet.

Classification tree analysis did not reveal simple patterns in deer road-kill distribution. Median width, percent cover, and building density are important characteristics in classifying deer road-kill density (figure 5.9). Areas with median width less than 12 meters were classified as low road-kill density. Areas with more than 6.5% cover, fewer than 11.5 buildings per square mile, median width greater than 59 meters, and less than 7.5 miles of road per square mile were classified as high road-kill density.

Analysis of elk road-kill densities (kills/mile) in relation to predicted movement cost for high mobility habitat generalist species showed an increase in elk kill density in areas predicted to be more permeable (figure 5.10). However, statistical evidence for the significance of this relationship was weak (linear regression F significance = 0.23).
In contrast to elk, deer kill density increased in areas with less predicted landscape permeability for high mobility habitat generalist species (linear regression F significance = 0.09).

Overall, the distribution of deer and elk road-kills in the study area reflects the natural history of these species. Deer are more tolerant of human disturbance than elk. The generally lower elevations, reduced cover, and less sensitivity to median width reflect this difference. Elk are more sensitive to human disturbance. Their use of areas with forested medians, hillsides, lower building density, higher elevation, and greater proximity to and percent cover all reflect this behavioral trait. In general, the distribution of crossing attempts by elk as represented by road-kill locations, is likely to be a better estimator of crossing locations for other species sensitive to human disturbance (including large carnivores) than deer crossing areas.

Table 5.1. Landscape-scale GIS habitat data used in the analysis of deer and elk road-kill distribution.

GIS Layer (attribute name)	**Description**
Median Width (WIDMED)	Median width in feet. Derived from WSDOT road log data.
Percent Cover (PCTCOV)	Percent of the area within a 0.5 mile radius with greater than 50% tree canopy closure. Derived from USFS PMR classified Landsat data, 1992 Image.
Distance to Cover (DTCOV)	Distance to cover patches (cover patches have greater than 50% tree canopy closure covering more than 3600 square meters), in meters. Derived from USFS PMR classified Landsat data, 1992 Image.
Slope (SLPAV)	Average slope (in degrees) within a 0.5 mile radius. Derived from USGS 1:24,000 digital elevation models.
Elevation (ELEV)	Elevation in meters. Derived from USGS 1:24,000 digital elevation models.
Road Density (RAWRDD)	Miles of all roads (including forest roads) per square mile. Derived from USFS Wenatchee National Forest corporate data.
Building Density (RAWBDD)	Number of buildings per square mile. Derived from USGS 1:24,000 CFF data, updated by hand from 1996 orthophoto quads.
Median Type (MEDB.A)	Median type was identified as grass (G), forest (F), or jersey barrier (J) from WSDOT road log data.
Paved Roadway Width (RDWID)	Paved roadway width in feet was calculated by summing the increasing and decreasing lane widths in the WSDOT road log data.
Topographic Position (TOPO.A)	Topographic position was classified as wide valley bottom (WVB), narrow valley bottom (NVB), lakeshore (LKS), or hillside (HLS) and hand digitized based on shaded relief maps and personal knowledge of the area.

Table 5.2. Differences in continuous landscape variables between available habitat and locations of deer and elk road-kills. Landscape variables were derived from GIS coverages (see table 5.1). Sample sizes are; deer n = 345, elk n = 102, available n = 2099.

Variable	Species	Mean	Std. Dev.	t-test, 2-tailed Significance	Mean Difference from available
Paved Roadway Width (ft)	Available	61.2	22.0		
	Deer	59.2	17.8	.06	-2.0
	Elk	59.0	17.6	.22	-2.2
Distance to Cover (m)	Available	112.7	71.3		
	Deer	118.4	67.0	.15	5.6
	Elk*	**99.3**	**57.8**	**.03**	**-13.4**
Percent Cover	Available	24.9	13.8		
	Deer	**23.2**	**13.4**	**.03**	**-1.7**
	Elk	**28.1**	**15.1**	**.04**	**3.2**
Slope (deg.)	Available	8.3	7.7		
	Deer	**7.1**	**5.9**	**.001**	**-1.2**
	Elk	8.5	7.6	.80	0.2
Road Density (mi/mi^2)	Available	6.8	2.7		
	Deer	6.6	3.2	.12	-0.3
	Elk	6.6	2.0	.31	-0.2
Building Density ($buildings/mi^2$)	Available	44.6	81.8		
	Deer	42.0	87.9	.60	-2.6
	Elk	**29.8**	**46.8**	**.003**	**-14.8**
Elevation (m)	Available	698.2	87.7		
	Deer	**679.2**	**83.0**	**<.001**	**-19.1**
	Elk	703.9	78.5	.48	5.7
Median Width (ft)	Available	130.8	259.5		
	Deer	147.0	264.0	.29	16.2
	Elk	**247.3**	**392.5**	**.004**	**116.5**

*Variables that show a t-test, 2-tailed significance less than 0.05 are shown in bold.

Table 5.3. Proportions of available area and observed deer and elk road-kill locations in relation to categorical landscape variables. Landscape variables were derived from GIS coverages (see table 5.1). Sample sizes are; deer n = 345, elk n = 102, available n = 2099.

Variable	Species	Proportion in each category				
Topographic Position		**Hillside**	**Lakeshore**	**Narrow Valley Bottom**	**Wide Valley Bottom**	**Pearson Chi-Square (df=2)**
	Available	0.18	0.05	0.08	0.69	
	Deer	**0.08**	**0.07**	**0.05**	**0.80**	**<0.001**
	Elk	0.21	0.08	0.04	0.68	0.23
Median Type		**Grass**	**Forested**	**Jersey Barrier**		
	Available	0.67	0.08	0.25		
	Deer	**0.84**	**0.08**	**0.07**		**<0.001**
	Elk	**0.73**	**0.19**	**0.09**		**<0.001**

*Variables that differ significantly (Pearson Chi-square <0.05) from available are shown in bold.

Figure 5.1. Deer and elk road-kills by year, 1990 to 1998, for I-90 in the vicinity of Snoqualmie Pass.

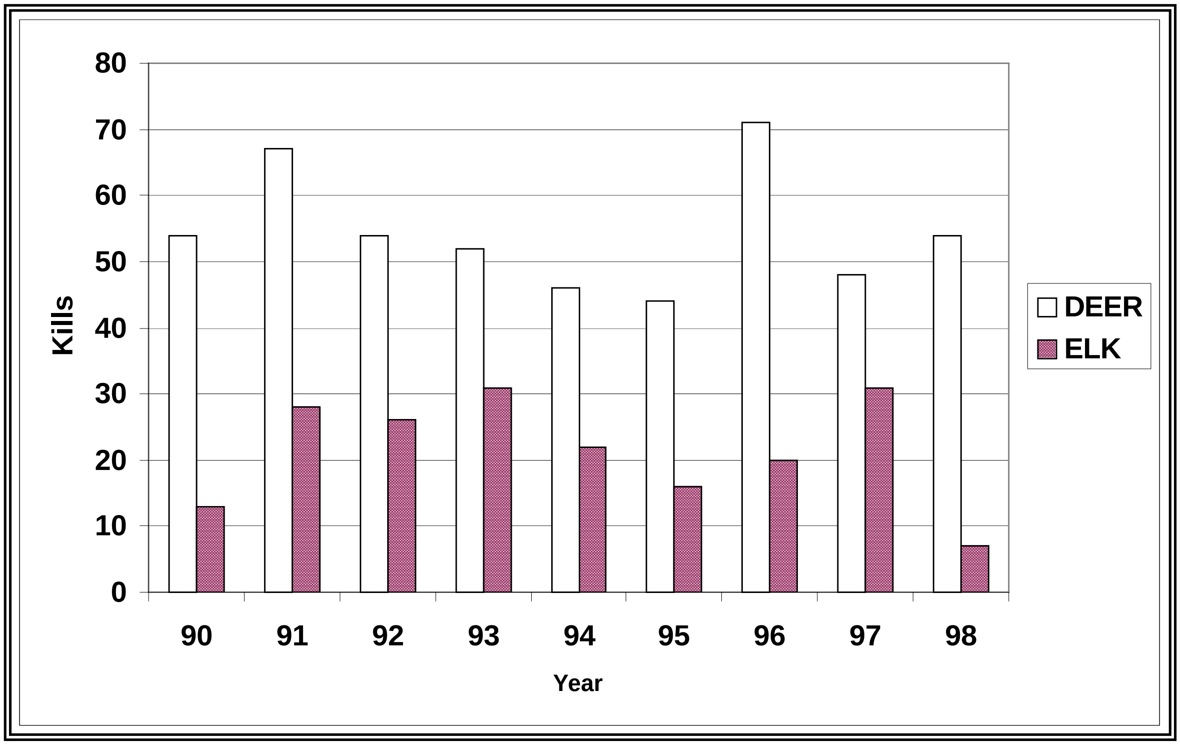


Figure 5.2. Deer and elk road-kills by month, 1990 to 1998, for I-90 in the vicinity of Snoqualmie Pass.

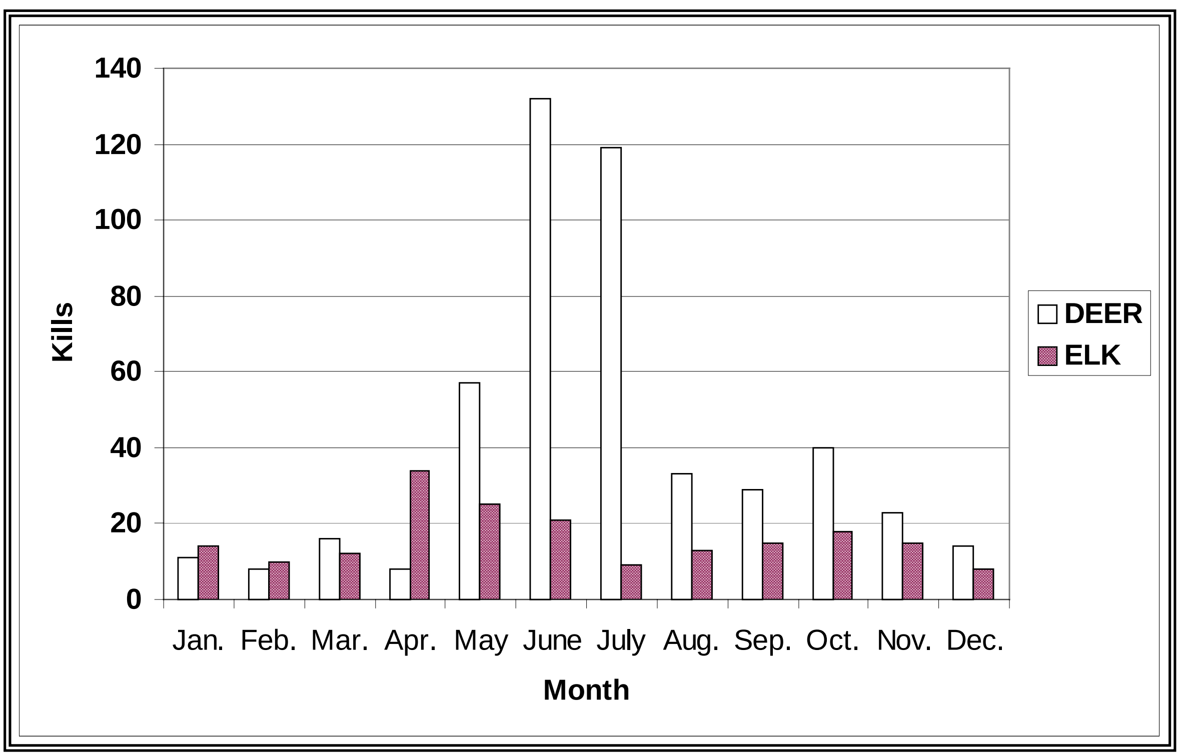
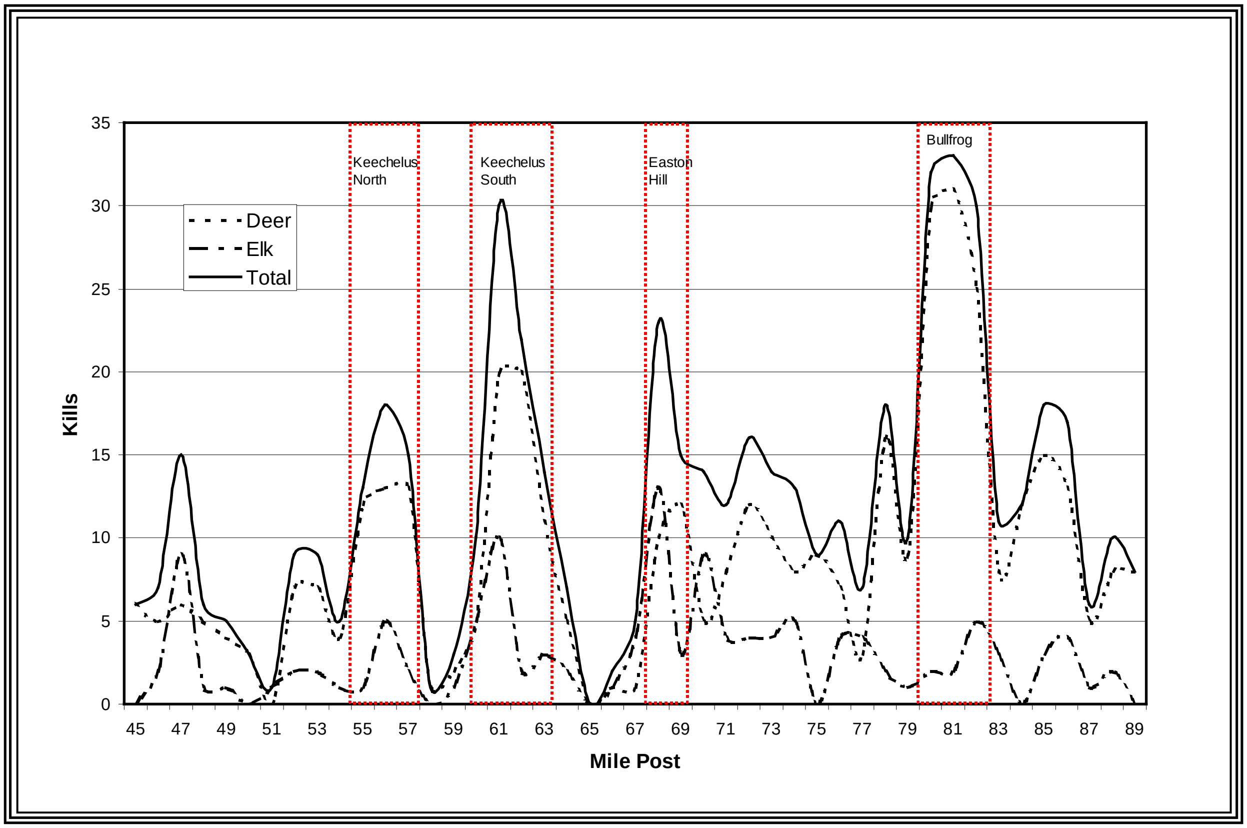


Figure 5.3. Ungulate road-kill distribution along I-90 in the vicinity of Snoqualmie Pass, 1990 to 1998.



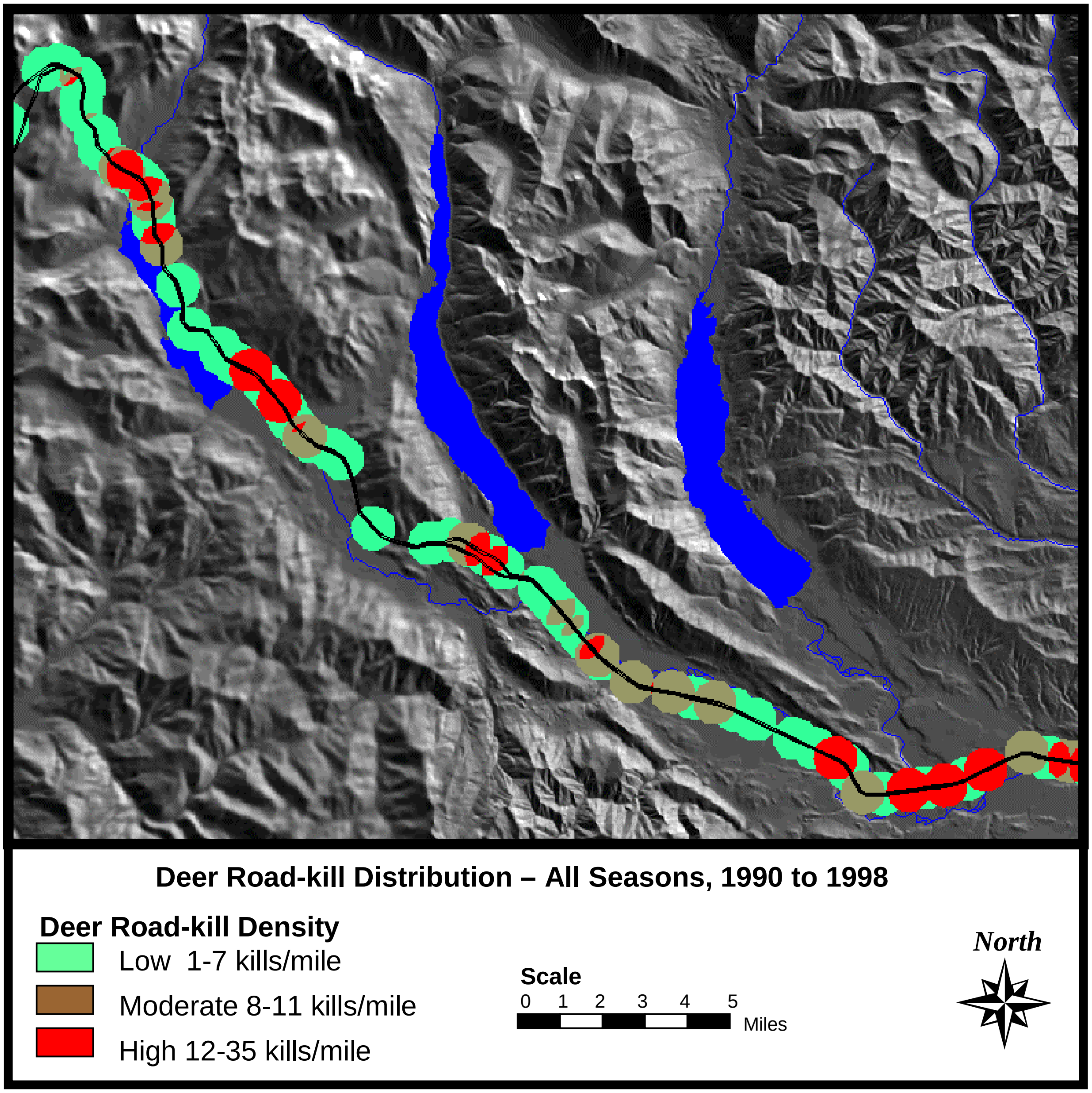


Figure 5.4. Total deer road kill distribution along I-90 for all seasons, from 1990 to 1998.

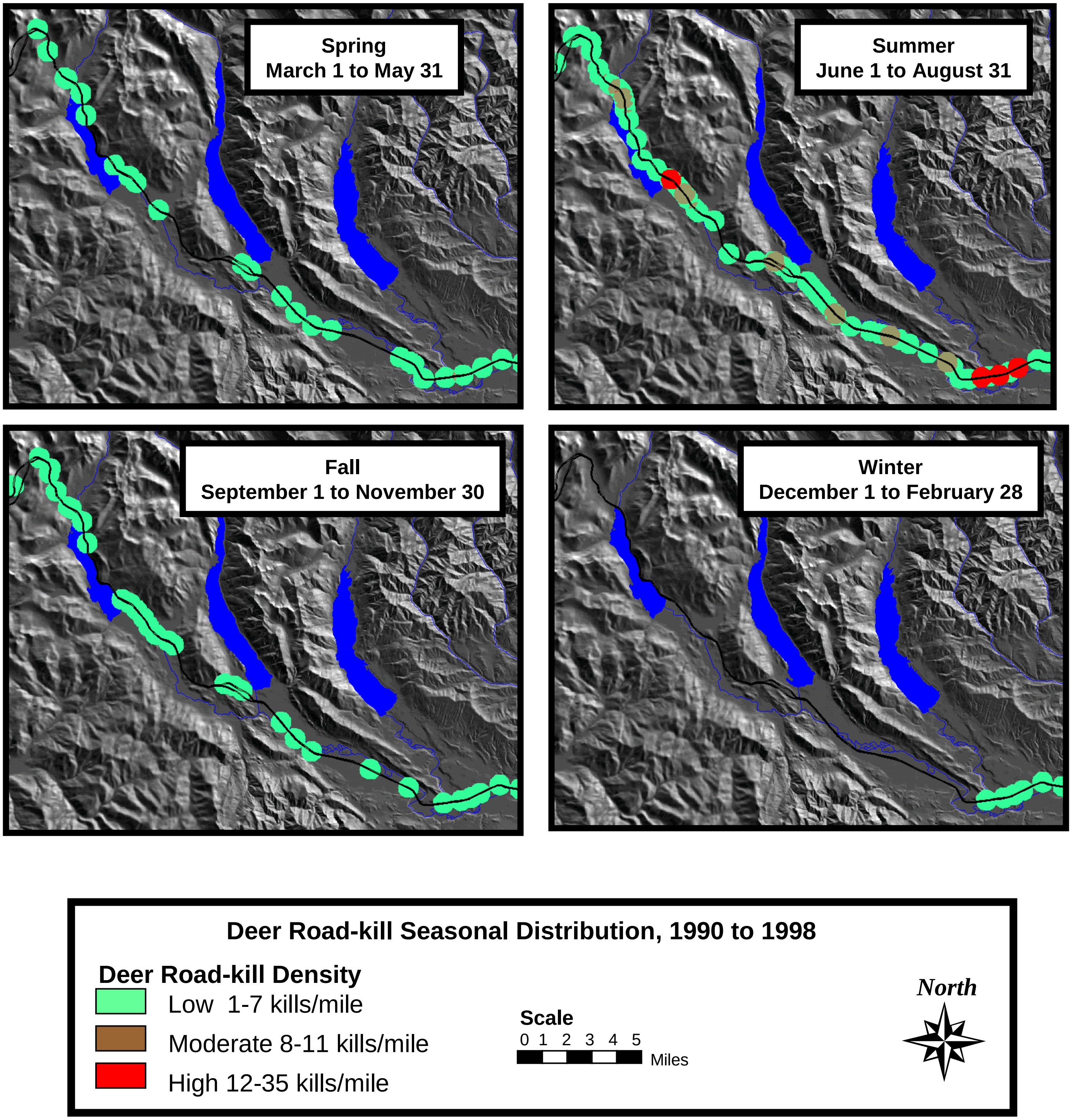


Figure 5.5. Deer road kill distribution along I-90 by season, from 1990 to 1998.

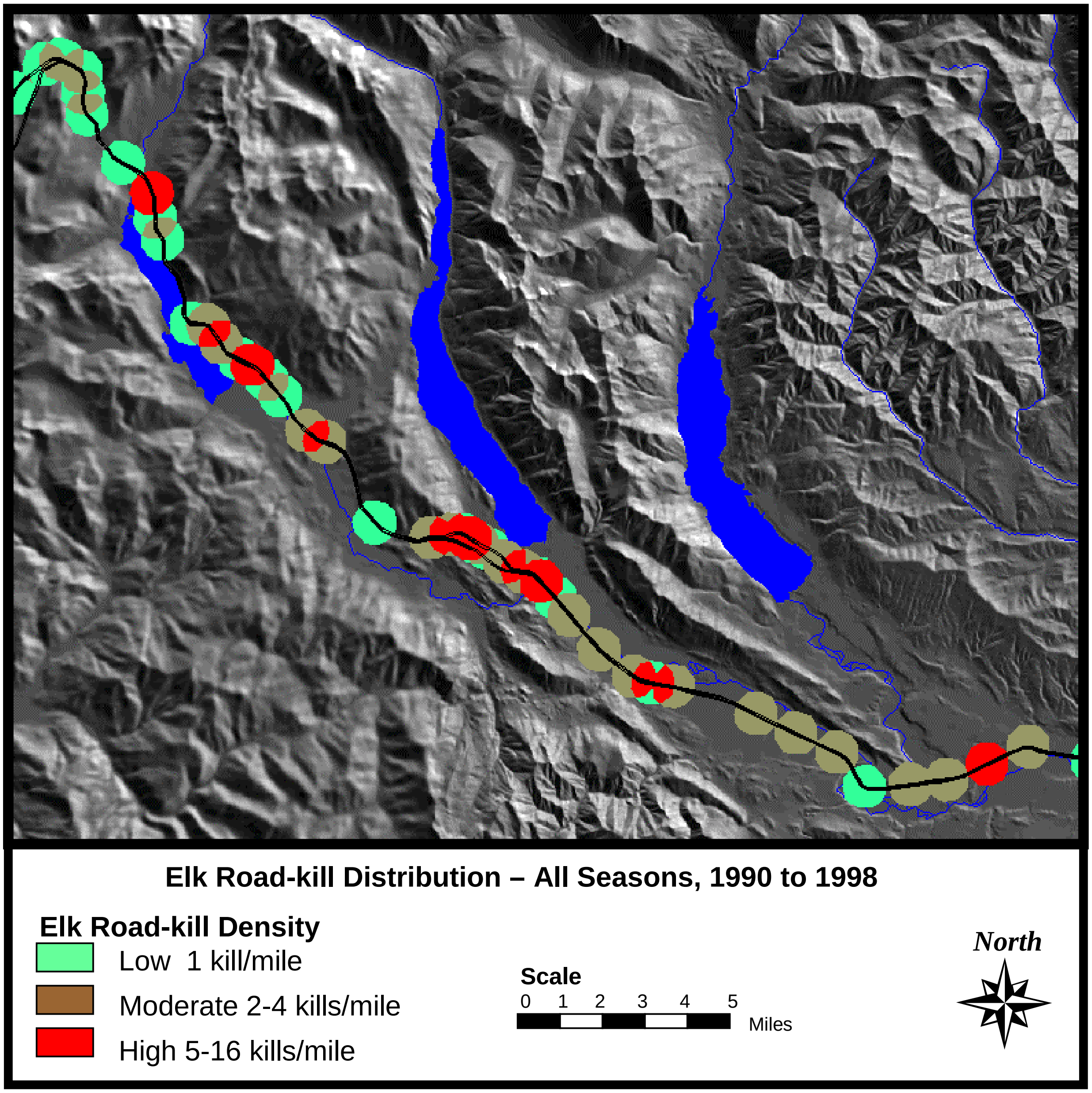


Figure 5.6. Total elk road kill distribution along I-90 for all seasons, from 1990 to 1998.

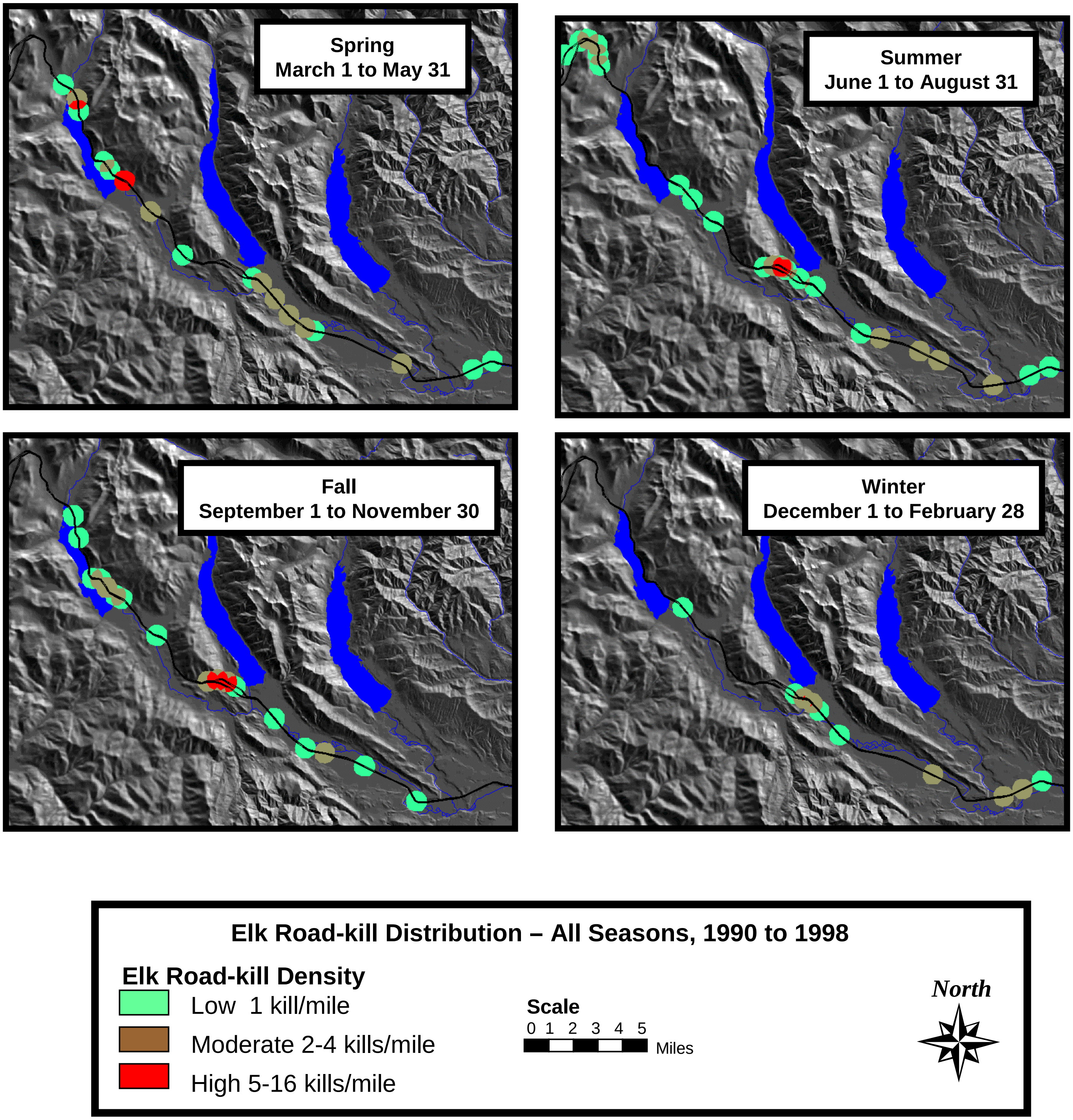


Figure 5.7. Elk road kill distribution along I-90 by season, for 1990 to 1998.

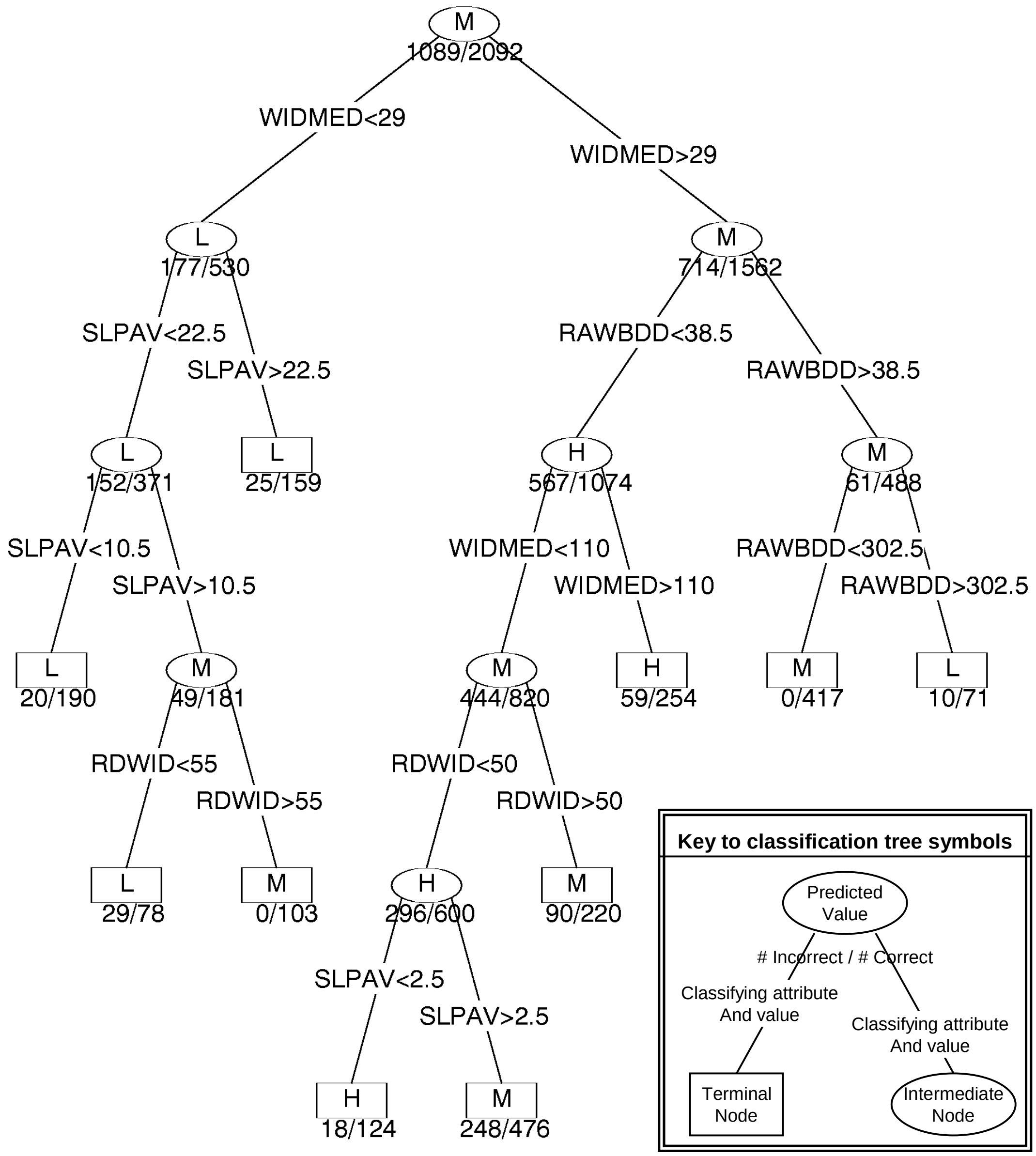


Figure 5.8. Elk road-kill density classification tree. This classification was developed from data on 2092 points derived from GIS data on elk road-kill density and landscape scale habitat characteristics. Elk density classes are; H = 5 to 16 kills per mile, M = 2 to 4 kills per mile, and L = 0 to 1 kills per mile. This classification correctly classifies 76.2% of the data (residual mean deviance = 1.03). Attribute names correspond to data sets described in table 5.1.

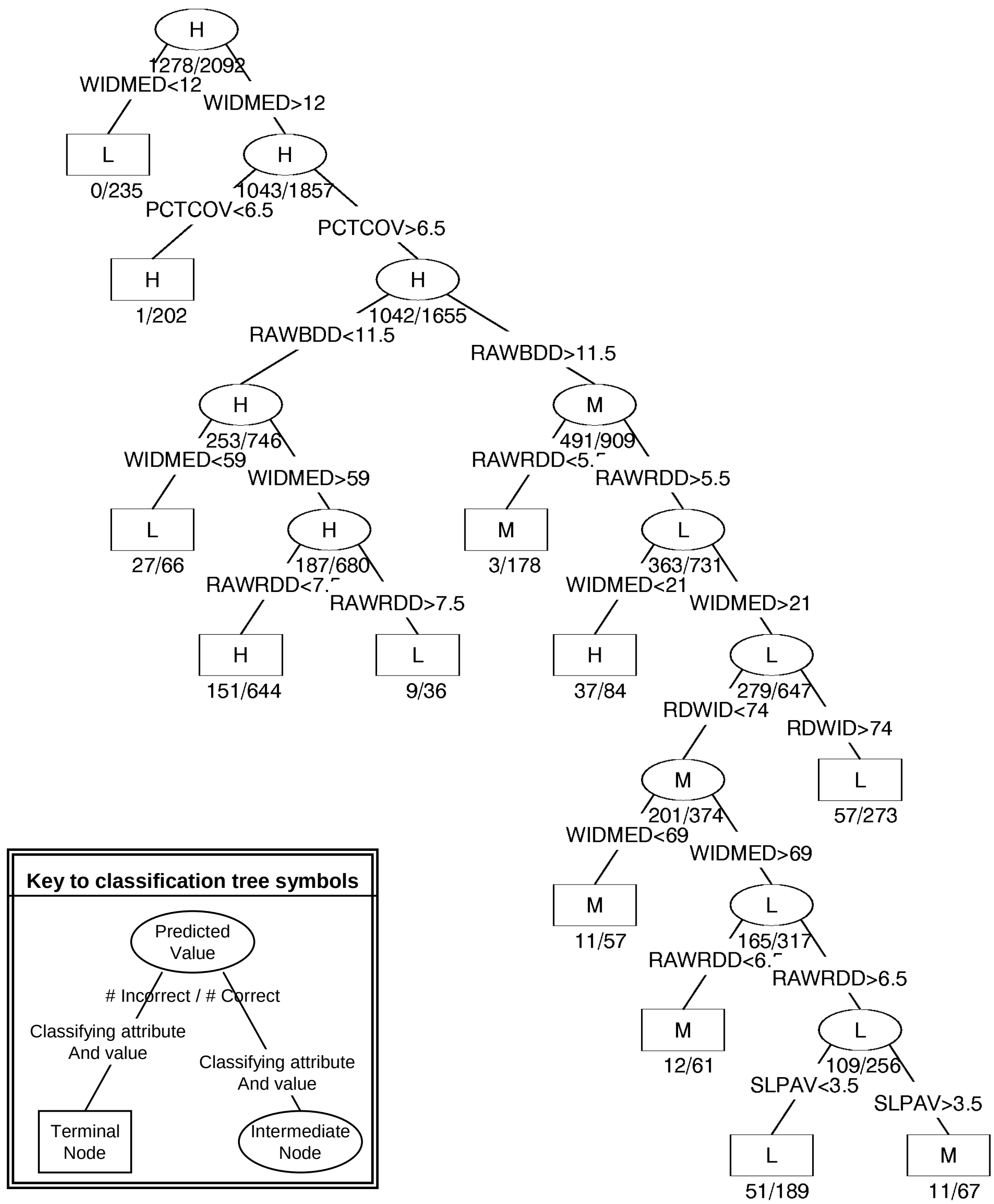
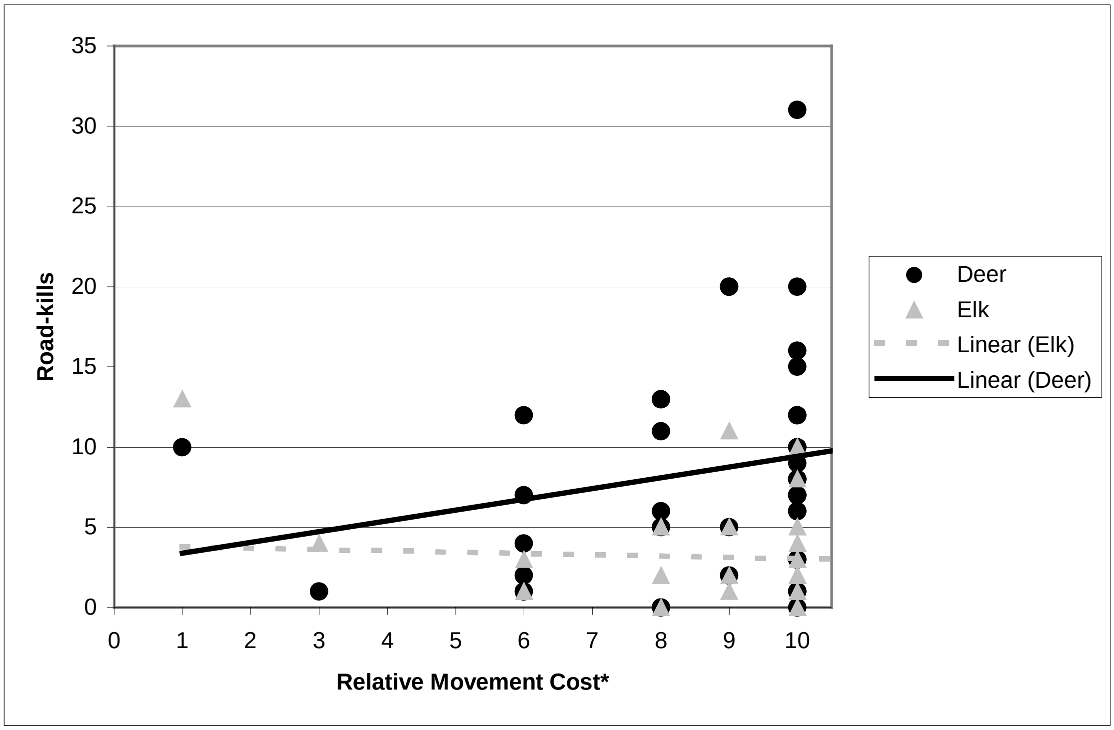


Figure 5.9. Deer road-kill density classification tree. This classification was developed from data on 2092 points derived from GIS data on deer road-kill density and landscape scale habitat characteristics. Deer density classes are; H = 12 to 35 kills per mile, M = 8 to 11 kills per mile, and L = 0 to 7 kills per mile. This classification correctly classifies 82.3% of the data (residual mean deviance = 0.93). Attribute names correspond to data sets described in table 5.1.

Figure 5.10. Deer and elk road-kill density at mileposts (n=38) compared to predicted landscape permeability for high mobility habitat generalist species. Areas with higher relative movement costs are expected to be less permeable to animal movement. Regression analysis indicated no significant relationship for elk (linear model; *number of road-kills = -0.28(movement cost),* F = 1.44 with 1 degree of freedom, F significance = 0.23, R^2 = 0.04) and a nearly significant relationship for deer (linear model; *number of road-kills = 0.97(movement cost)*, F = 3.11 with 1 degree of freedom, F significance = 0.09, R^2 = 0.08).



* Relative movement cost was identified by grouping the landscape into 10 classes of equal area based on landscape permeability. Areas with movement cost = 0 were predicted to be the most permeable 10% of the landscape, while areas with movement cost = 10 were predicted to be least permeable 10% of the landscape.

6) Snow Tracking Surveys

6.1) Introduction

We conducted snow tracking surveys from January to March 1999 and December to March 2000 to identify wildlife crossing locations, and evaluate winter animal distribution in the highway corridor. Other fieldwork for this project focused on documenting presence of wildlife in the vicinity of the highway with automatic camera stations, and evaluating wildlife use of existing highway structures. While automatic camera stations and highway structure monitoring are important components of this project, these techniques do not address the questions of what species cross over the roadway surface and precisely where these crossings occur. Our objective was to identify crossing locations using snow-tracking techniques.

6.2) Methods

We employed snow tracking techniques similar to those used by researchers in Banff National Park, Alberta (Alexander 1998). Snow tracking transects were laid out to sample representative portions of the highway corridor based on the highway sections identified for highway structure monitoring and preliminary habitat connectivity model runs (figure 6.1). The highway corridor in each section was stratified by habitat linkage probability from preliminary landscape connectivity models. In each of the 5 highway sections, 1 mile long transects were located on both sides of the highway, in the areas with good and poor predicted linkage values. In the winter of 1999, we surveyed tracks along 4 transects in each highway section (except section 3, which had 2 transects because of dangerous terrain on the north side of the highway). Transects were assigned identifying codes based on section (section 1 through 5), predicted linkage value (A for better linkage, B for poorer linkage), and side of the highway (N or S, e.g. 2BN). Five tracking transects were added for the winter of 2000 (1CN, 1CS, 4CN, 4CS, and 5C) based on results from automatic camera surveys and ungulate road kill distribution analysis. One pair of transects that was surveyed in 1999 was not surveyed in 2000 (1BN and 1BS) because of the level of human disturbance along the transect.

Surveys were conducted by skiing or snowshoeing approximately 150 meters away from the highway for the length of the transect. Surveys were generally conducted between 24 and 72 hours after the most recent snowfall. Whenever possible, 2 researchers in radio contact surveyed the north and south sides of the highway simultaneously and all transects in a highway section were surveyed on the same day. All animals larger than snowshoe hare were recorded, and the location marked on a topographic map. We followed tracks in the direction of the highway to determine animal behavior in relation to the highway. When tracks were documented entering and exiting on opposite sides of the highway, within 300 meters, going in the same direction, a ‘confirmed crossing’ was recorded. Tracks only documented entering or exiting the highway, but believed to be locations where animals crossed the highway, were considered ‘unconfirmed crossings’. Other tracks recorded along the transect were recorded as non-crossing detections.

We calculated binomial probabilities (Zar 1999, p. 518) to test if detection rates of regularly detected species in each highway section were different from the species average detection rate across all sections. To assist in validation of the landscape permeability model for high mobility habitat generalists, we used linear regression analysis to investigate the relationship between coyote and bobcat detections and average predicted linkage value along each tracking transect.

6.3) Results

A total of 235 animal detections were recorded during 29 sets of snow tracking surveys (2 to 4 transects in each set) conducted between January 19 and March 11, 1999 (table 6.1). Two-hundred and eighty-three animal detections were recorded along 31 sets of tracking surveys between December 21 and March 20, 2000. Snow tracking efforts covered 103 and 150 miles of tracking transects during the 1999 and 2000 field seasons respectively. Wildlife species regularly detected along tracking transects were coyote, bobcat, and elk. Humans and dogs were also regularly detected. Porcupine, striped skunk, deer, raccoon, red fox, and domestic cat were recorded infrequently (table 6.2, figures 6.1 through 6.6). Smaller mammals including snowshoe hare and Douglas squirrel were regularly detected but were not recorded along transects.

Some authors have suggested weighting snow track detection rates by time since snowfall to calculate indices of abundance, assuming that more tracks will be left as animals have more time to move through the study area (Beauvais and Buskirk 1999). We conducted regression analysis comparing total animal detections to time elapsed between the last track obscuring snowfall for all 237 tracking transects. Animal detection rates were not substantially related to time since last snowfall ($R^2 < 0.01$, F significance = 0.18) and the slope of any relationship was insubstantial (y = 0.007). We therefore believe that the percentage of surveys during which a species was detected is an appropriate index of abundance for comparison between groups of transects for this data.

Coyotes and bobcat were the most commonly detected species during snow tracking surveys. These species were not evenly distributed throughout the study area. Compared to their average detection rate for all highway sections (36% of surveys, table 6.2), coyotes were detected significantly more often along the Easton Hill (50% of surveys, $p < 0.01$), and Keechelus South (44% of surveys, $p = 0.04$) highway sections, and less often in the Yakima Valley (16% of surveys, $p = 0.01$). Bobcat were the second most common wild species, and were detected most often along Amabalis Mtn. (35% of surveys, $p = 0.01$) and Easton Hill (21% of surveys, $p = 0.09$) and significantly less often in the Yakima Valley (5% of surveys, $p = 0.02$) and Snoqualmie Pass (3% of surveys, $p < 0.01$). Detection rates of coyote and bobcat were higher in areas with good predicted linkage value. Linear regression of coyote and bobcat detection rates in relation to predicted landscape permeability indicated that there was a significant relationship between detection rates for both species and predicted landscape permeability for high mobility habitat generalists (figure 6.7).

People were detected regularly in all highway sections (average 20% of surveys) excepting Amabalis Mtn. (4% of surveys), and were detected significantly more often in the Yakima Valley (48% of surveys, $p = 0.05$) and Snoqualmie Pass (67% of surveys, p <

0.01). People and dogs were most often recorded in areas with poorer predicted landscape permeability for high mobility habitat generalists.

Sixty-seven highway crossings were recorded during the 2 winters of snow tracking (table 6.3). Raccoons were recorded crossing the highway 5 times, all in the Yakima Valley during 1999. Coyotes made 49 highway crossings, 29 of which were along Easton Hill and 13 along the Keechelus South section. Thirteen crossings by bobcat were recorded, 9 along Easton Hill, 3 in the Keechelus South area, and 1 near Big Creek in the Yakima Valley. The bobcat crossing in the Yakima Valley was made in 1999 while the highway was closed for avalanche control. Seventy-three percent of the highway crossings recorded during snow tracking surveys were in the Easton Hill section. Crossings were infrequently documented in the Yakima Valley, Amabilis Mtn., and Snoqualmie Pass sections.

Finer scale investigation of crossing locations indicates that crossings were relatively clustered in distribution (figures 6.3 and 6.5). Two clusters of crossing locations occurred in the Keechelus South section (figure 6.5); 1) milepost 61.9 to 62.5 where 5 coyote crossings were recorded in 2000, and 2) milepost 63.2 to 63.8 where 4 coyote and 3 bobcat crossings were recorded in 2000 and 1 coyote crossing was recorded in 1999. Along the Easton Hill section, 6 clusters of highway crossings occurred (figure 6.3); 1) west bound lanes at milepost 67.5 to 67.9 where 3 coyote and 2 bobcat were recorded crossing in 2000 and 3 coyote and 1 bobcat were recorded crossing in 1999, 2) east bound lanes at mile post 68.0 to 68.3 where 3 coyote crossings were recorded in 2000 and 2 coyote and 1 bobcat crossings were recorded in 1999, 3) west bound lanes at milepost 68.2 to 68.3 where 2 coyote crossings were recorded in 2000 and 1 coyote crossing was recorded in 1999, 4) east bound lanes at milepost 68.5 to 68.7 where 3 coyote and 1 bobcat were recorded crossing in 1999, 5) west bound lanes at milepost 68.6 to 68.8 where 2 coyote crossings were recorded in 2000 and 1 coyote crossing was recorded in 1999, and 6) east bound lanes at milepost 68.9 to 69.0 where 5 coyote crossings were recorded in 1999 and 1 bobcat crossing was recorded in 2000. A total of 35 coyote and 9 bobcat crossings occurred in these 8 areas, representing 2.5 miles of highway. In other words, 66% of all recorded crossings occurred along approximately 13% of the highway length covered by snow tracking surveys.

Table 6.1. Snow tracking transects completed during the I-90 Snoqualmie Pass Linkage Assessment. Hours between track surveys and the last track obscuring snowfall are indicated in parenthesis.

Highway Section	Date (Hours elapsed between snowfall and tracking)								Number of Surveys
	1999 Snow Tracking Surveys								
1	1/19 (24)	1/27 (98)	2/5 (24)	2/12 (48)	2/24 (36)	3/1 (48)			6
2	1/20 (12)	2/5 (24)	2/11 (24)	2/24 (24)	3/2 (24)	3/8 (72)	3/11 (24)		7
3	1/19 (24)	2/3 (24)	2/12 (48)	3/2 (24)	3/8 (72)	3/11 (48)			6
4	1/25 (48)	2/11 (24)	3/2 (24)	3/8 (72)	3/11 (24)				5
5	1/25 (48)	2/11 (24)	3/2 (24)	3/8 (24)	3/11 (48)				5
	2000 Snow Tracking Surveys								
1	1/7 (72)	1/19 (78)	1/28 (48)	2/2 (24)	2/16 (36)				5
2	1/6 (48)	1/14 (12)	1/20 (12)	2/16 (36)	3/1 (78)				5
3	1/7 (72)	1/19 (78)	1/25 (10)	2/7 (36)	2/17 (60)	2/26-28 (36)			6
4	12/21-29 (48)	1/6-10 (48)	1/24 (78)	2/17 (60)	3/1 (78)	3/15 (24)	3/20 (24)		7
5	12/23-28 (78)	1/18 (72)	1/27 (24)	2/3 (48)	2/17 (60)	3/3 (36)	3/15 (24)	3/20 (24)	8

Table 6.2. Detection rates by highway section for animals detected on snow tracking transects along I-90 during winter 1999 and 2000. Bold columns indicate areas where the percent of surveys during which a species was detected differed significantly (binomial test 2-sided significance < 0.05) from the average percent of surveys the species was detected at across all highway sections. Binomial probabilities were calculated only for the regularly detected species.

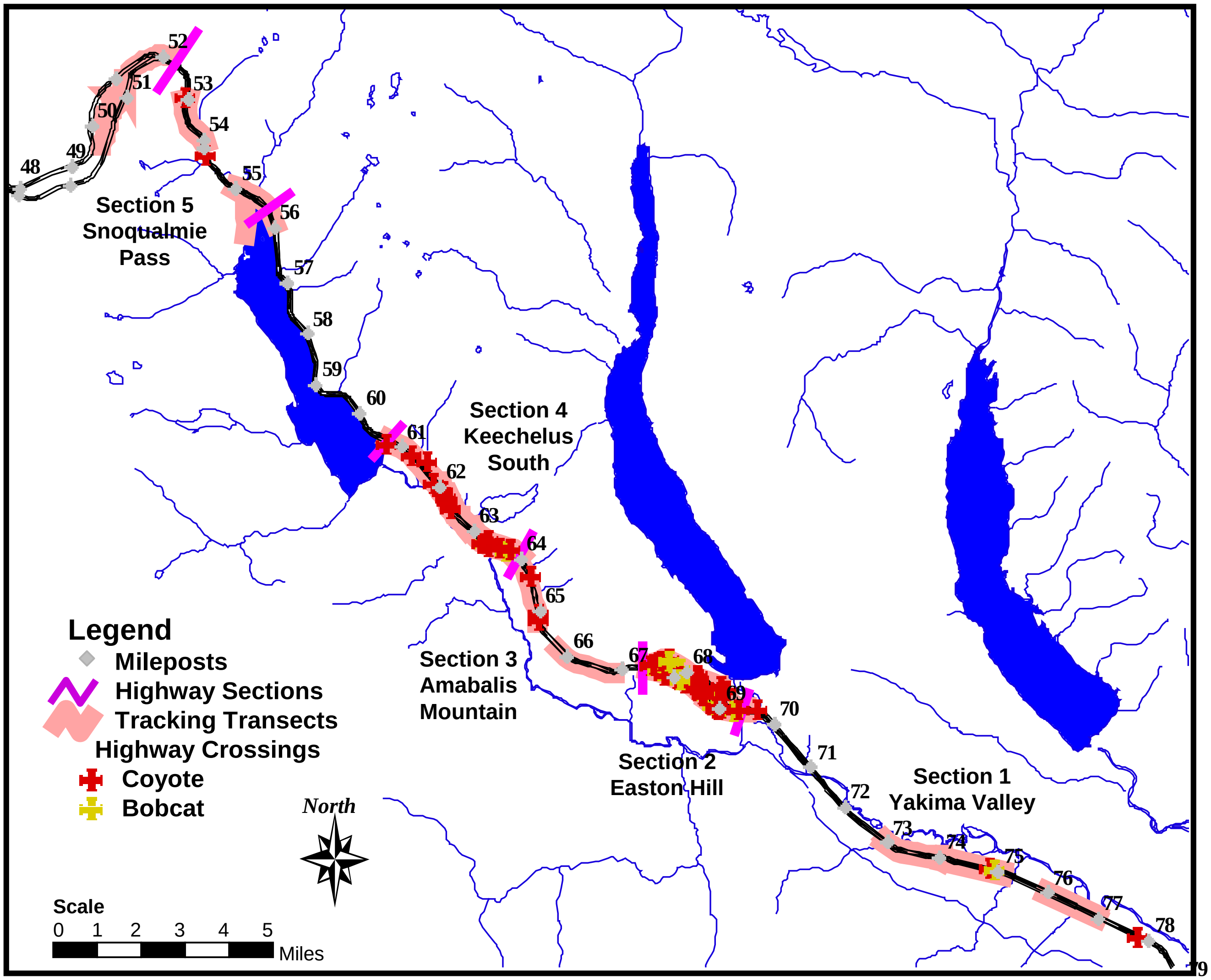
		Highway Section					
		1	**2**	**3**	**4**	**5**	**All Sections**
	n[a]	44	48	23	62	60	237
Coyote	No. Detections[b]	**11**	**50**	12	**47**	28	148
	Pct. Surveys[c]	**16%**	**50%**	35%	**44%**	33%	36%
	P[d]	**<0.01**	**0.01**	0.17	**0.04**	0.10	
Human	No. Detections	**26**	18	**1**	42	**63**	150
	Pct. Surveys	**48%**	33%	**4%**	40%	**67%**	38%
	P	**0.05**	0.09	**<0.01**	0.10	**<0.01**	
Dog	No. Detections	**19**	7	**0**	13	**28**	67
	Pct. Surveys	**34%**	15%	**0%**	18%	**33%**	20%
	P	**0.01**	0.10	**0.01**	0.12	**0.01**	
Bobcat	No. Detections	**3**	**17**	**10**	10	**2**	42
	Pct. Surveys	**5%**	**21%**	**35%**	13%	**3%**	15%
	P	**0.02**	**0.09**	**0.01**	0.13	**<0.01**	
Elk	No. Detections	4	**10**	0	0	0	14
	Pct. Surveys	5%	**13%**	0%	0%	0%	3%
	P	0.26	**0.01**	0.43	0.10	0.11	
Domestic Cat	No. Detections	9	0	0	0	1	10
	Pct. Surveys	20%	0%	0%	0%	2%	8%
Raccoon	No. Detections	9	0	0	0	0	9
	Pct. Surveys	16%	0%	0%	0%	0%	7%
Deer	No. Detections	6	0	0	1	0	7
	Pct. Surveys	14%	0%	0%	2%	0%	6%
Porcupine	No. Detections	1	0	0	0	0	1
	Pct. Surveys	2%	0%	0%	0%	0%	0.4%
Striped Skunk	No. Detections	1	0	0	0	0	1
	Pct. Surveys	2%	0%	0%	0%	0%	0.4%
Red Fox	No. Detections	0	0	0	1	0	1
	Pct. Surveys	0%	0%	0%	2%	0%	0.4%
American Marten	No. Detections	0	0	0	0	1	1
	Pct. Surveys	0%	0%	0%	0%	2%	0.4%

[a]Number of 1 mile transects surveyed.
[b]Total detections recorded for the species. Some species were detected more than once while surveying a transect.
[c]Percent of surveys during which the species was detected.
[d]Binomial test 2-sided probability (Zar 1999, p. 518) that the sample proportion (proportion of surveys the species was detected at) for each highway section is derived from a population that, with a very large sample size, would have the same detection rate as the average detection rate across all highway sections for that species.

Table 6.3. Summary of highway crossings by wildlife documented during snow tracking transects, January to March 1999 and January to March 2000.

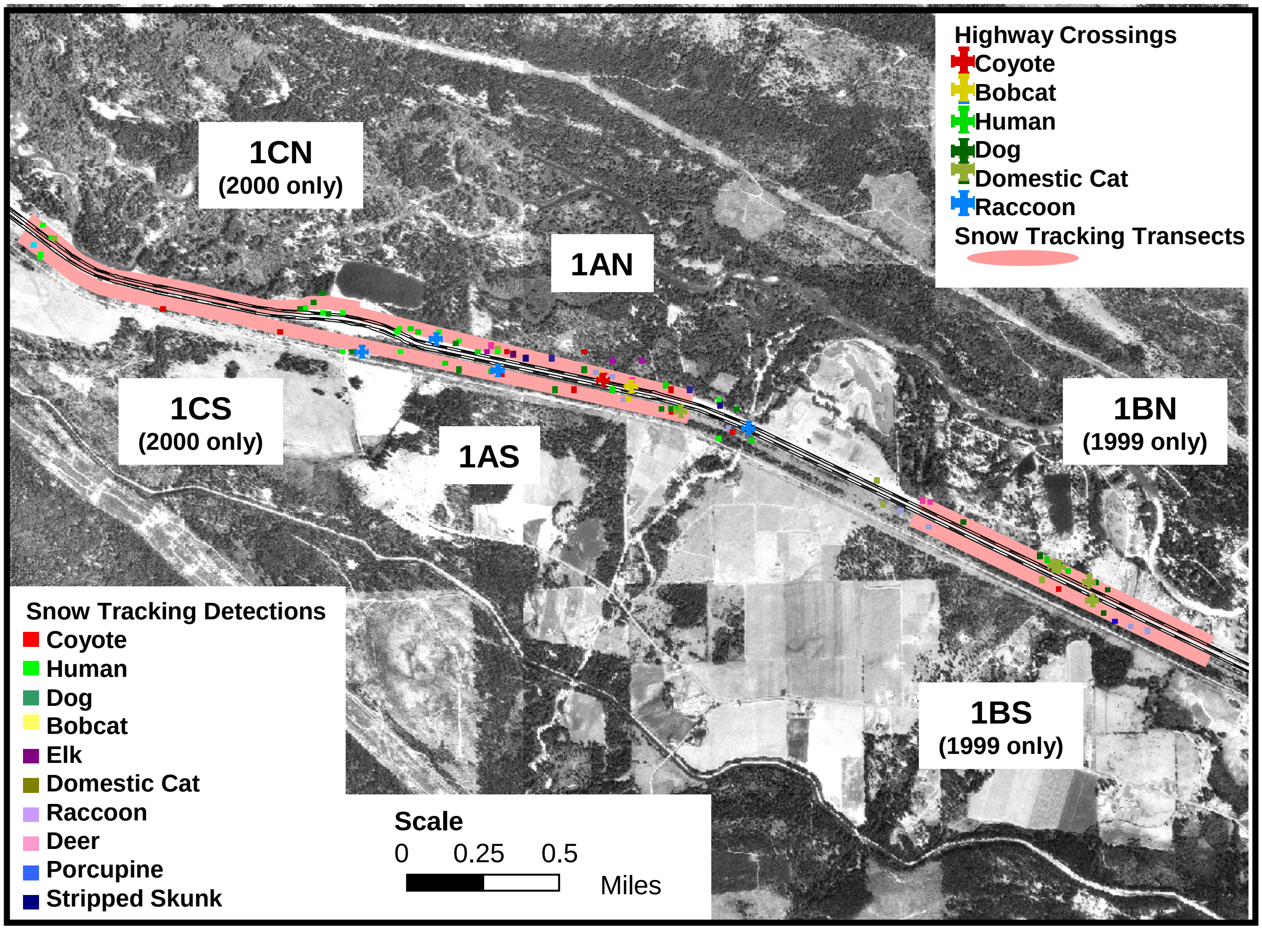
Species	Crossing Type	Highway Section 1	2	3*	4	5	1999 Total	2000 Total	Grand Total
Coyote	**Confirmed**	2	22		5	1	20	10	30
	Unconfirmed		7	3	8	1	8	11	19
Bobcat	**Confirmed**	1	6				3	4	7
	Unconfirmed		3		3		1	5	6
Raccoon	**Confirmed**	4					4	0	4
	Unconfirmed	1					1	0	1
1999 Total		7	23	2	4	1	37		
2000 Total		1	15	1	12	1		30	
Grand Total		8	38	3	16	2			67

* No tracking transects were located on the north side of section 3 due to safety concerns. All crossings were recorded from the south side as unconfirmed for this section.



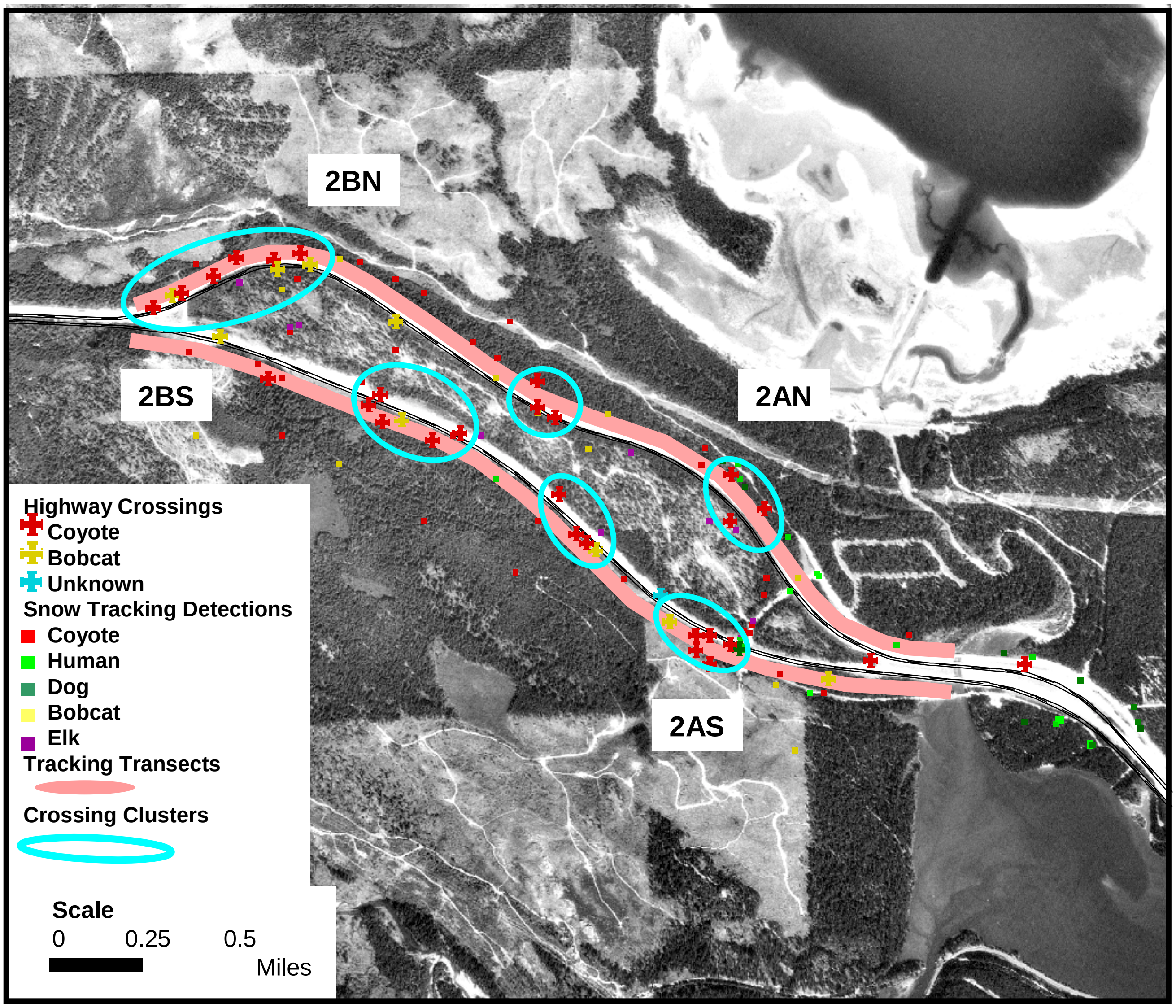
Snow Tracking Transect and Highway Crossing Locations

Figure 6.1. Transect locations and highway crossings from snow tracking surveys conducted during winter 1999 and 2000 along I-90 in the vicinity of Snoqualmie Pass.



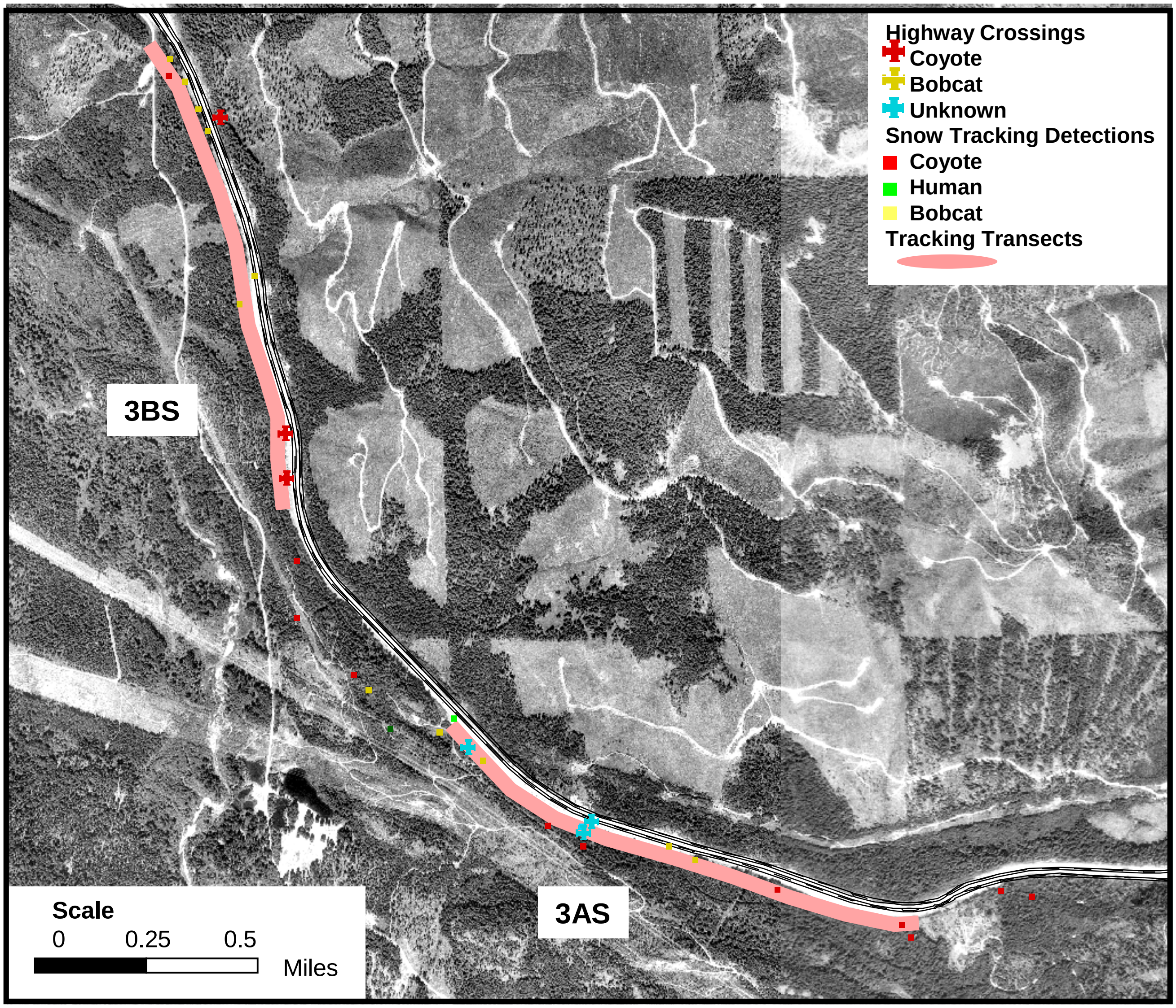
Section 1, Yakima Valley – Snow Tracking Survey Results

Figure 6.2. Snow tracking transects, animal detections, and highway crossing locations for for snow tracking surveys conducted during the winters of 1999 and 2000 along highway section 1, Yakima Valley.



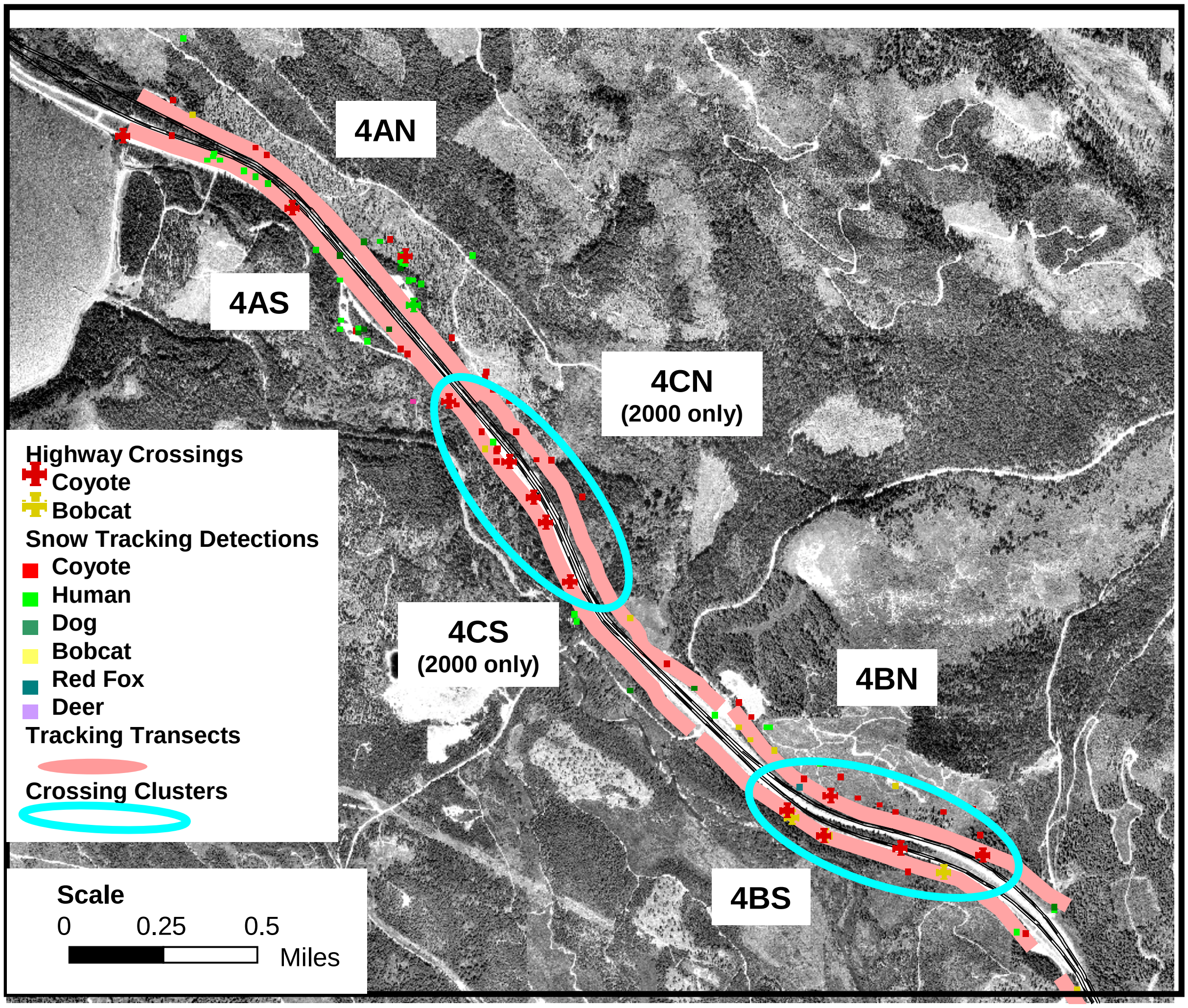
Section 2, Easton Hill – Snow Tracking Survey Results

Figure 6.3 Snow tracking transects, animal detections, and highway crossing locations for for snow tracking surveys conducted during the winters of 1999 and 2000 along highway section 2, Easton Hill.



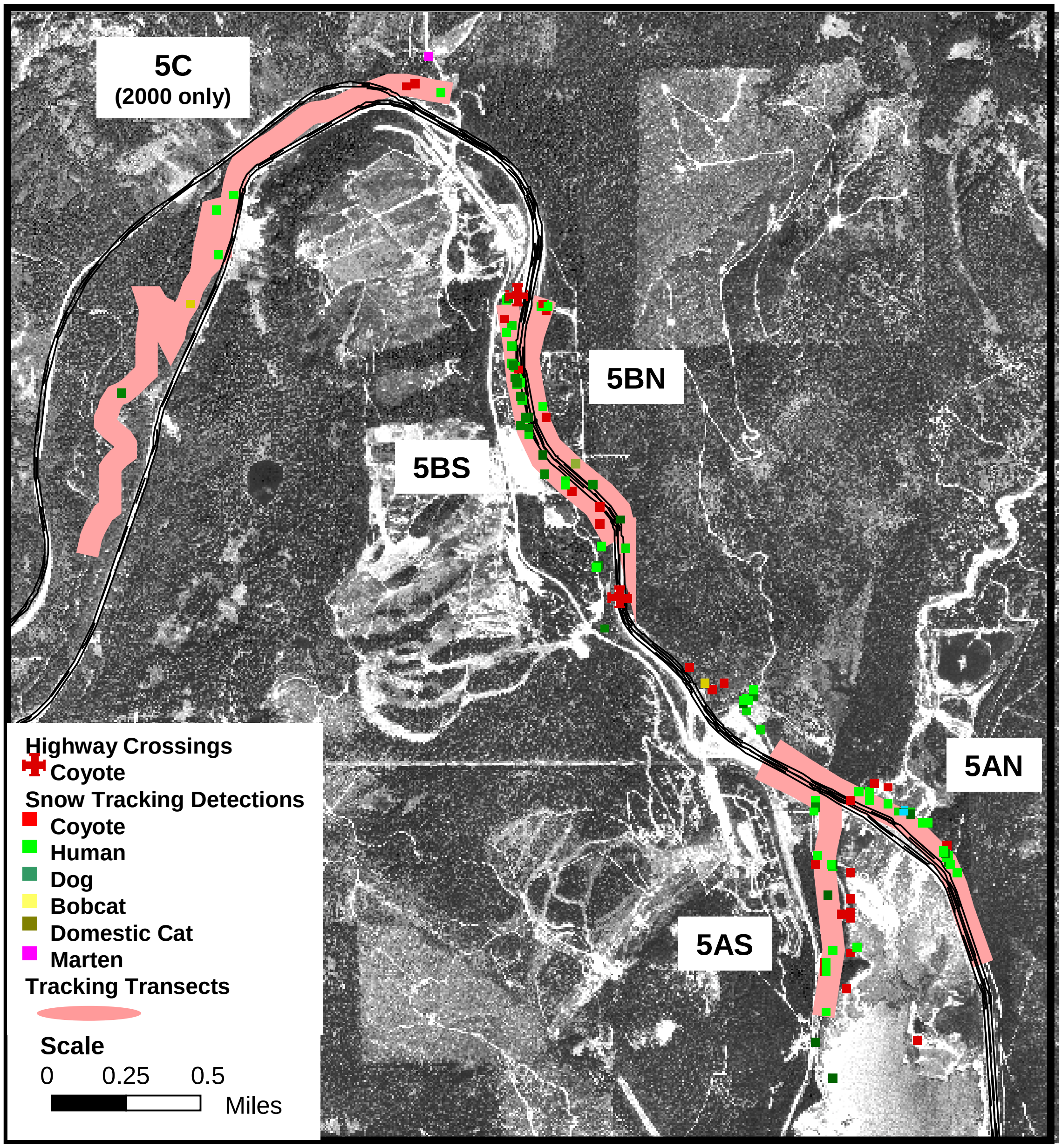
Section 3, Amabilis Mtn. – Snow Tracking Survey Results

Figure 6.4. Snow tracking transects, animal detections, and highway crossing locations for for snow tracking surveys conducted during the winters of 1999 and 2000 along highway section 3, Amabilis Mtn.



Section 4, Keechelus South – Snow Tracking Survey Results

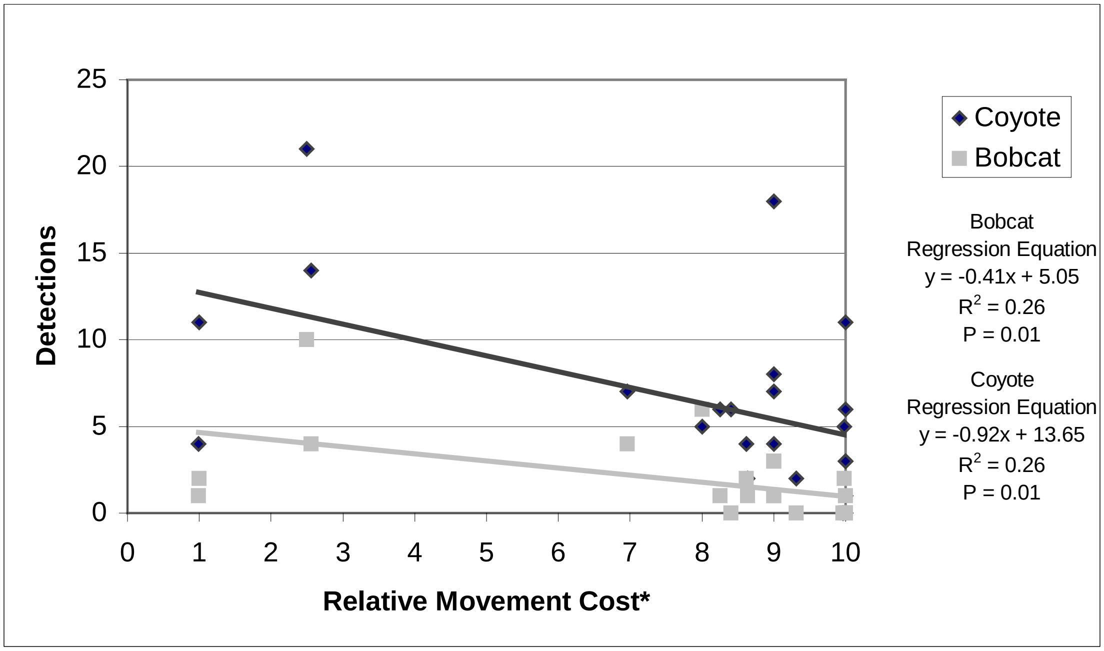
Figure 6.5. Snow tracking transects, animal detections, and highway crossing locations for for snow tracking surveys conducted during the winters of 1999 and 2000 along highway section 4, Keechelus South.



Section 5, Snoqualmie Pass – Snow Tracking Survey Results

Figure 6.6. Snow tracking transects, animal detections, and highway crossing locations for for snow tracking surveys conducted during the winters of 1999 and 2000 along highway section 5, Snoqualmie Pass.

Figure 6.7. Snow tracking transect detections of coyote and bobcat in relation to predicted landscape permeability from least-cost path modeling for high mobility habitat generalist species (using USFS PMR data). Number of detections for each species were compared to average movement cost for each transect (n = 23). Areas with higher relative movement costs are expected to be less permeable to animal movement. Regression analysis indicated a significant relationship between detection rate and predicted movement cost for both coyote and bobcat.



* Relative movement cost was identified by grouping the landscape into 10 classes of equal area based on landscape permeability. Areas with movement cost = 0 were predicted to be the most permeable 10% of the landscape, while areas with movement cost = 10 were predicted to be least permeable 10% of the landscape.

7) Highway Structure Monitoring

7.1) Introduction

Roads, particularly heavily traveled interstate highways, can constitute substantial barriers to animal movement (Beier 1995, Brody and Pelton 1989, Mansergh and Scotts 1989). Structures associated with standard highway construction (e.g. bridges and culverts) have been documented to provide passage through these barriers for some wildlife species (LeBlanc 1994, Rodriguez et al. 1996, Yanes et al. 1995, Clevenger and Waltho 1999). We monitored existing highway structures along I-90 for wildlife movements from June 24 to October 30, 1998. Our objective was to determine what species use existing structures to cross I-90, and to evaluate the characteristics of existing highway structures used by wildlife.

7.2) Methods

We mapped all underpasses, overpasses, and culverts along I-90 from Denny Creek (milepost 48) to Cle Elum (milepost 81). Major structures (e.g. bridges and overpasses) were mapped using GIS layers provided by WSDOT. Culverts were mapped using GPS. All culverts greater than 18 inches in diameter that were detected from the road were mapped. Structure size, length, habitat conditions and other information were recorded for all structures. Habitat data gathered at monitored culverts is summarized in table 7.1.

Culverts were numbered by the corresponding mile marker and assigned a consecutive letter according to the order in which they were inventoried (usually east to west, e.g. 67C). Structures identified from WSDOT GIS data were numbered consecutively, from east to west, and given a G prefix (G1 through G17)

Within each highway segment, we selected structures to monitor based on size, distance to cover, and expected wildlife passage potential. We also monitored all bridges and large box culverts that could be monitored without substantial risk of loss of equipment. Our objective in selecting structures to monitor was to sample as many of the different types of highway structures as possible, and distribute the monitoring across the study area.

Monitoring techniques included cameras, track plates, and tracking beds. Initial monitoring efforts emphasized automatic cameras (Trailmaster TM500 passive infrared monitors and TM35-1 cameras). For monitoring larger structures (usually concrete box culverts or bridges), cameras were mounted inside the passage to be triggered when animals went by. For monitoring smaller culverts (less than approximately 0.75 meter diameter), we initially mounted cameras outside of the structure so that they would be triggered when an animal entered or exited the structure. This technique was unsatisfactory. Sooted track plates proved to be the most effective technique for monitoring animal passage in smaller structures (less than 1m, figure 7.1). Raked tracking beds were also effective for monitoring larger structures that had sandy riverbanks or other suitable substrate for tracking. No bait was used in any highway structures.

Detections of all species were recorded. Detections were classified as crossings if a species was detected at both ends of a structure, going in the same direction, or if tracks or photos were collected in the middle of the passage (as was usually the case for larger structures such as bridges).

Structures were monitored for a minimum of 28 days between June 24 and October 15, 1998. Monitoring was limited to summer and early fall by seasonal rainfall and inundation of drainage culverts. Because of the ease of maintaining tracking beds and plates, some structures were monitored for substantially longer periods. The largest bridges were monitored for the entire field season. Initial plans for this study included 2 seasons of structure monitoring. However, Forest Service funding was not available for structure monitoring in 1999.

T-tests (SPSS ver. 9.0) and classification tree analysis (S-Plus 2000) were conducted to compare habitat characteristics of structures where individuals of a species were recorded to those where the species was not recorded. T-tests were conducted for all species detected in more than 1 structure. Classification tree analysis was conducted for those species detected in 4 or more structures. To standardize detection effort, structures were considered used if an individual of that species was detected in the structure in the first 30 days of monitoring. Results of this analysis should be considered preliminary due to limited sample size and potential bias from different detection techniques.

To confirm species identification from track plates and to compare small mammal use of culverts to presence outside of culverts, we conducted small mammal live trapping in and adjacent to culverts where small mammals had been documented in 1998. The small mammal trapping was conducted from August 16 to 26, 1999. Two Sherman traps were placed approximately 4 feet inside of the culvert and 2 traps were placed approximately 4 feet away from the mouth of the culvert on the outside. Traps were placed at both ends of the culvert.

Regression tree analysis was used to evaluate the characteristics of structures in which small mammals were trapped during August 1999 (S-Plus 2000). Capture ratios were calculated for each structure according to the following formula:

$$\textit{Capture Ratio} = \frac{\textit{Captures per trap night inside the culvert}}{\textit{Captures per trap night outside the culvert} + 0.05}$$

This transformation provides an index of use that considers the capture rate inside the culvert compared to the capture rate outside the culvert, and compensates for division by zero errors when calculating the ratio. We then used regression tree analysis to identify classification rules that predict capture ratios for each species trapped in culverts.

7.3) Results

Fifty-eight culverts and 21 major structures were mapped in the highway study section between Snoqualmie Pass (milepost 52) and Cle Elum (milepost 81, figures 7.2 through 7.5). In addition, 51 culverts and 3 major structures were mapped between Snoqualmie

Pass and Denny Creek (milepost 48), for possible future monitoring. Twenty-nine structures (24 culverts and 5 bridges) were monitored for at least the minimum of 28 nights. One structure (G6) was monitored for 23 nights. We removed the camera early from this structure because of the frequency of human use and the theft of a camera from an adjacent structure. Two other structures (G5 and 70A) were dropped from monitoring efforts because of theft or vandalism of cameras. Four camera sets were stolen, and 1 vandalized, during the course of the field season.

Monitoring at each highway structure ranged in duration from 23 to 124 nights between June 24 and October 15 (mean 66.1). Monitoring duration varied with detection method used due to differences in effort required and number of cameras available. Average duration for camera monitored structures was 38 nights (N = 15, range 23 to 57 nights). Tracking bed monitored structures were monitored for the entire field season (mean 123 nights, N = 3, range 123 to 124 nights). Average duration for tracking plate monitored structures was 86 nights (N = 12, range 66 to 103 nights).

We conducted a total of 1983 detection nights at highway structures. We recorded 1554 animal detections and 324 crossings (including humans and pets). Of these, 1132 detections and 264 crossings were wild mammals. Twenty-three species or groups of species were detected (including humans and pets, table 7.2). Fifteen of the taxa were wild mammals. Wild mammals were detected in 26 of the 30 monitored structures. Crossings were recorded at 20 of the structures.

On average, a species was detected within 21 nights of monitoring (range 1 to 112 nights, SD 23.9). The average dropped to 16 nights (range 1 to 110 nights, SD 7.8) when only wild mammals were considered (excluding porcupine, which was detected at one bridge after 112 nights of monitoring). Latency to detection varied by detection method. Track plates had the lowest average nights to first detection of a species (average 8, range 1 to 47, SD 7), followed by cameras (average 18, range 1 to 76, SD 16), and tracking beds (average 38, range 1 to 110, SD 36).

Quantitative analysis of habitat and structure characteristics in relation to animal passage was confounded by substantial variation in species detectability by monitoring method. Significantly more species were detected during the first 28 days of monitoring at stations with track plates or beds than at those using cameras (t-test $p < 0.01$). Three stations were monitored with concurrent use of track plates and cameras and 1 station with concurrent use of tracking bed and camera. Cameras recorded substantially fewer detections than track plates or beds at these stations (table 7.3).

Five taxa constituted 68% (1064) of the 1554 detections and 81% (263) of the 324 crossings recorded. These taxa are mice (23% of detections), chipmunks (14%), squirrels (14%), striped skunk (9%), and humans (9%). The small mammal taxa (chipmunks, mice, and squirrels) were detected at all structures monitored with tracking techniques (beds and plates) and consisted of 74% of the crossings recorded for wild mammals.

Nine species of wild mammals, including mule deer, porcupine, weasels, raccoon and small mammals, were recorded crossing the highway under the 6 bridges monitored in 1998. No carnivores larger than raccoon and no elk were recorded crossing the highway under bridges, though elk, coyote, bobcat, and black bear were recorded at camera stations near monitored bridges.

Carnivores detected in highway structures included striped skunk (12 structures), weasel (10 structures), raccoon (7 structures), river otter (1 structure), and American marten (1 structure). Weasel were detected in culverts that were closer to forest, had more tree canopy closure, higher basal area, less grass cover within 5 meters, and were narrower than unused culverts (table 7.4). Culverts where raccoon were detected were in or near the roadside clear zone, farther from both forest and the road, had lower basal area, less canopy closure, less herb and shrub cover, and more grass cover than unused culverts. There were no significant differences in habitat characteristics between culverts used and unused by striped skunks. Classification tree analysis identified canopy closure as an important classification variable for skunk (used culverts were more than 2.5 meters from forest or had less than 63% canopy closure) and weasel (used culverts had greater than 31% tree canopy closure at the mouth) (figure 7.6). The structures where river otter and American marten were photographed (structure 62A and 54B respectively) were large (approximately 1.75 x 1.75 meter) box culverts associated with perennial streams and late successional forest nearby.

Humans and their pets (domestic dogs and cats) composed 17% of all detections and crossings. Culverts used by domestic cats were generally in or near the roadside clear zone, closer to the road, had low basal area, low canopy closure, less shrub cover, and more grass cover than unused culverts (table 7.4). In the classification tree analysis, 3 out of 4 culverts used by domestic cats were classified based on a higher percent of grass at the culvert mouth (figure 7.6). Culverts used by humans were in or near the roadside clear zone, were larger, had lower basal area, and were closer to the road than unused culverts. Most human use was at larger box culverts and bridges in the area east of Easton Lake. One human crossing through a 0.6 meter drainage culvert was documented with track plates in this area. Streams and riverbanks under bridges were regularly used for recreational activities (swimming, fishing, and campfires). On average, structures used by humans had lower numbers of species detected (2.3 compared to 3.7, t-test $p = 0.12$). This difference may be due to differences in monitoring techniques used at the larger structures frequented by people, however human use is likely to limit the attractiveness of these larger structures for passage by species sensitive to human disturbance.

Other taxa detected while monitoring highway structures included frogs, lizards, snakes, mollusks, and insects. These taxa were not identified to species. No crossings were documented for these taxa. Frogs were found in 4 drainage culverts ranging in size from 0.5 to 1.2 meters. Usually these culverts had small amounts of standing or flowing water and were adjacent to wetland habitats. Lizards and snakes were generally detected in tracking beds at the bridges, though a lizard was detected 4 times at a dry 0.5 meter metal drainage culvert.

Some small mammal taxa are difficult to identify to species from tracks and were therefore grouped by size during the 1998 monitoring. Most of those classified as mice are expected to be Deer Mice (*Peromyscus sp.*), and chipmunks probably include yellow-pine and Townsend's chipmunks. Mice, chipmunks, Douglas squirrel, and western jumping mouse used culverts that were on average smaller and opened farther from the road than unused culverts (table 7.4). Height was also the most important variable in classification tree analysis for mice, Douglas squirrels, chipmunks, and jumping mice (figure 7.6). Culverts used by these small mammals also averaged more canopy closure and basal area than unused culverts, though the difference was significant only for western jumping mouse. The only species for which culvert length differed significantly between used and unused culverts was bushy-tailed woodrat (used culverts were on average shorter than unused culverts, table 7.4).

Small mammal trapping in culverts during August 1999 yielded 205 captures of 10 species (table 7.5). Regression tree analysis of the total capture ratio indicated that the percent of the ground covered by grass at the mouth of the culvert, distance to the road, length of the structure, distance to forest, and canopy closure were important variables for evaluating total capture rate (figure 7.7). Structures with the highest capture ratio were characterized by greater than 12.5% grass cover at the mouth of the structure, less than 11.5 meters to the road, and less than 4 meters to forest. Structures with the lowest capture ratio were characterized as having less than 12.5% grass cover at the mouth of the structure, greater than 37 meters in length, and between 5 and 15 meters from the road.

Deer mice (*Peromyscus spp.*) were the most commonly captured species both inside (82% of captures) and outside of culverts (84% of captures, table 7.5). Deer mice were captured inside culverts at 53% of the stations and outside at 91%. Regression tree analysis indicated that percent of the ground at the mouth of the culvert covered by shrubs, gravel, or bare, distance to forest, canopy closure, and height of the structure were important variables for characterizing capture ratios for deer mice (figure 7.7).

Other taxa were captured in 2 to 5 structures. Such sample sizes are too small to develop predictive models, however regression tree analysis can suggest some patterns in the data (figure 7.7). Voles were captured in structures with more than 47.5% of the area within 5 meters of the mouth of the structure covered by grass. Weasels were captured in structures with openings more than 24.5 meters from the road. Chipmunks were captured in structures higher than 105 centimeters or more than 11.5 meters from the roadside clear zone. Jumping mice were trapped in culverts higher than 52 centimeters and with more than 42% of the ground within 5 meters of the mouth covered by shrubs. Bushy-tailed Woodrats were trapped in 1 structure, which was less than 37 meters in length.

The results of our highway structure monitoring indicate that dry drainage structures may provide important movement routes for small mammals crossing highway corridors. Many of the species that we detected in culverts would face considerable mortality risk while crossing over the highway surface and adjacent clear zones (both from direct vehicle mortality and predation). Dry drainage structures provide relatively secure passageways for small mammal movement. This preliminary investigation indicates that habitat at the mouth of the culvert is potentially more important than culvert length in providing for small mammal passage.

While many of the species we detected in dry drainage structures were relatively common (e.g. deer mice) these species serve important ecological functions such as providing dispersal mechanisms for seeds and fungal spores. Provision of opportunities for small mammals associated with late successional forests to cross the highway corridor through dry drainage culverts could prove to be important in maintaining some ecological functions of old forest patches divided by highways.

Table 7.1. Habitat and structure characteristics recorded at drainage culverts monitored for wildlife passage.

Characteristic	**Description**
Structure Characteristics	
Length	Length of the structure as measured by laser viewfinder, in meters.
Height	Internal height of the structure, in centimeters.
Width	Internal width of the structure, in centimeters.
Site Characteristics	
Slope	Percent slope averaged for a 5 meter radius area centered on the mouth of the structure.
Aspect	Azimuth averaged for a 5 meter radius area centered on the mouth of the structure.
Distance from road surface (To Road)	Planimetric distance to paved road surface in meters.
Distance from clear zone (To Clear)	Planimetric distance to the roadside clear zone.
Distance to shrub cover (To Shrub)	Distance, in meters, to shrubs >0.75 meters tall and covering an area >2.5 meters radius.
Distance to forest (To Forest)	Distance, in meters, to forest cover (areas with >50% canopy closure and 15 meters in diameter).
Vegetation Characteristics	
Canopy Closure	Percent canopy closure for a 5 meter radius area centered on the mouth of the structure.
Percent shrub cover (Shrub)	Percent of the 5 meter radius area centered on the mouth of the structure covered by shrubs.
Percent herb cover (Herbs)	Percent of the 5 meter radius area centered on the mouth of the structure covered by herbs.
Percent grass cover (Grass)	Percent of the 5 meter radius area centered on the mouth of the structure covered by grass.
Percent bare (Bare)	Percent of the 5 meter radius area centered on the mouth of the structure with bare ground.
Percent gravel (Gravel)	Percent of the 5 meter radius area centered on the mouth of the structure covered by gravel (usually associated with the road shoulder or traction sand).

Table 7.2. Total detections, total documented highway crossings, and the number of structures detected in or crossed through for wild mammals recorded in highway drainage culverts or under highway bridges along I-90. Monitoring was conducted at 29 structures for a total of 1983 detection nights. Detection methods included automatic cameras, tracking plates, and tracking beds.

Species	Total Detections	Total Crossings	Number of Culverts Detected	Number of Culverts Crossed	Number of Bridges Crossed
Mice*	351	78	14	6	3
Chipmunk species*	217	55	15	13	3
Douglas Squirrel	213	48	14	6	3
Striped Skunk	139	36	10	6	2
Western Jumping Mouse	63	15	9	5	1
Bushy-tailed Woodrat	51	16	7	5	0
Mule Deer	46	5	1	0	5
Raccoon	16	2	5	1	2
Hoary Marmot	14	2	1	1	0
Weasel species	12	4	10	4	1
Snowshoe Hare	5	1	2	1	0
Opossum	2	0	1	0	0
River Otter	1	1	1	1	0
American Marten	1	1	1	1	0
Porcupine	1	0	0	0	1

*Probably includes other similar sized small mammals.

Table 7.3. Number of animal detections at I-90 highway structure monitoring stations during concurrent monitoring with cameras and tracking techniques. Concurrent monitoring was conducted at 4 structures, with automatic cameras and tracking plates or tracking beds, from June 24 to October 15, 1998.

	Structure (Dates Monitored)							
	68B (6/30-7/22 & 8/25-9/29)		68C (6/30-7/22 & 8/25-9/15)		72C (8/22-9/25)		74B (7/7-8/7 & 9/25-10/6)	
Species	**Camera**	**Plates**	**Camera**	**Plates**	**Camera**	**Plates**	**Camera**	**Bed**
Chipmunk		14		5		3		3
Domestic Cat						1		9
Human							1	5
Mice		28		2		4		6
Pacific Jumping Mouse						1		
Raccoon						3		1
Squirrel	2	29	1	4		2		3
Striped Skunk						1		1
No Photo[a]	1							
Unexplained[b]	19		21					
Unknown[c]	1		1					3

[a] Monitor registered detection, but no photo was taken.
[b] Unexplained photo, no reason for detection apparent from photo (animal may have passed out of field of view of camera).
[c] Unknown, animal not identifiable from photo or tracks.

Table 7.4. Habitat characteristics of 21 culverts where animals were detected during highway structure monitoring from June to October 1998. Habitat variables are described in table 7.1. Detection techniques included track plates, track beds, and automatic cameras.

	Habitat Characteristics	Used		Unused		t-test 2-tailed significance*
		Mean	Std. Error	Mean	Std. Error	
Chipmunk Used n = 15 Unused n = 6	Basal Area	6.2	1.4	5.0	3.0	0.73
	Canopy Closure	30.5	6.4	23.0	10.1	0.54
	% Bare	7.7	1.9	10.5	1.1	0.22
	% Grass	21.7	4.4	23.2	1.9	0.76
	% Gravel	19.9	3.5	21.5	4.6	0.79
	% Herb	23.0	5.0	16.3	3.8	0.30
	% Shrub	23.8	3.8	19.8	5.3	0.56
	% Other	5.0	1.9	7.7	5.2	0.65
	To clear zone (m)	2.8	1.1	1.2	1.0	0.27
	To forest (m)	19.8	8.6	12.3	6.4	0.50
	To road (m)	10.7	1.9	6.7	1.1	0.09
	To shrub (m)	7.4	3.4	3.3	0.9	0.27
	Height (cm)	***75.3***	***11.2***	***125.0***	***13.3***	***0.01***
	Length (cm)	53.7	3.5	55.3	8.4	0.87
	Width (cm)	85.5	16.4	176.7	58.7	0.19
Douglas Squirrel Used n = 14 Unused n = 7	Basal Area	6.6	1.4	4.3	2.6	0.45
	Canopy Closure	32.2	6.6	20.7	8.9	0.32
	% Bare	8.9	2.0	7.6	1.8	0.62
	% Grass	21.9	4.7	22.4	2.3	0.92
	% Gravel	19.6	3.7	22.0	4.1	0.67
	% Herb	23.4	5.4	16.6	3.3	0.29
	% Shrub	22.6	4.1	22.7	4.6	0.99
	% Other	4.6	1.9	8.0	4.7	0.53
	To clear zone (m)	2.9	1.1	1.1	0.8	0.22
	To forest (m)	17.4	8.9	18.3	7.9	0.94
	To road (m)	***11.4***	***2.0***	***6.0***	***1.0***	***0.03***
	To shrub (m)	7.5	3.7	3.7	1.3	0.35
	Height (cm)	***67.3***	***8.3***	***134.0***	***14.6***	***<0.01***
	Length (cm)	50.9	3.5	60.9	6.8	0.22
	Width (cm)	73.9	12.3	186.9	50.8	0.07
Mice Used n = 13 Unused n = 8	Basal Area	6.9	1.5	4.1	2.3	0.33
	Canopy Closure	34.0	6.9	19.2	7.8	0.18
	% Bare	8.6	2.1	8.2	1.7	0.89
	% Grass	21.3	5.1	23.4	2.2	0.71
	% Gravel	18.1	3.4	24.0	4.1	0.30
	% Herb	24.4	5.7	15.7	2.9	0.19
	% Shrub	24.0	4.2	20.5	4.6	0.58
	% Other	4.6	2.1	7.6	4.1	0.52
	To clear zone (m)	3.1	1.2	1.0	0.7	0.14
	To forest (m)	18.2	9.5	16.7	7.0	0.90
	To road (m)	***11.5***	***2.1***	***6.4***	***1.0***	***0.04***
	To shrub (m)	7.7	4.0	3.9	1.1	0.37
	Height (cm)	***63.2***	***7.8***	***132.2***	***12.8***	***<0.01***
	Length (cm)	51.7	3.7	58.2	6.5	0.40
	Width (cm)	***70.3***	***13.7***	***178.5***	***44.8***	***0.05***

* Indicates the probability that the sample means for used and unused structures could be derived from populations that with a much larger sample size would have the same mean. T-tests were conducted using SPSS ver. 9.0, 2 sided significance, equal variances not assumed are reported here.

Table 7.4 (continued). Habitat characteristics of 21 culverts where animals were detected during highway structure monitoring from June to October 1998. Habitat variables are described in table 7.1. Detection techniques included track plates, track beds, and automatic cameras.

	Habitat Characteristics	Used		Unused		t-test 2-tailed significance*
		Mean	Std. Error	Mean	Std. Error	
Jumping Mouse Used n = 8 Unused n = 13	Basal Area	8.7	2.0	4.1	1.5	0.09
	Canopy Closure	***54.9***	***8.7***	***19.5***	***5.6***	***0.04***
	% Bare	6.5	1.8	9.7	2.0	0.25
	% Grass	17.7	6.9	24.8	2.9	0.37
	% Gravel	14.4	4.6	24.1	3.1	0.11
	% Herb	30.1	8.6	15.5	2.1	0.14
	% Shrub	26.2	5.7	20.5	3.5	0.41
	% Other	6.5	3.1	5.3	2.7	0.77
	To clear zone (m)	4.5	1.8	1.0	0.5	0.09
	To forest (m)	7.7	4.7	23.8	9.6	0.15
	To road (m)	13.0	3.1	7.5	1.1	0.13
	To shrub (m)	5.0	2.3	7.0	3.8	0.66
	Height (cm)	***53.9***	***5.7***	***111.5***	***12.4***	***<0.01***
	Length (cm)	52.6	5.7	55.1	4.3	0.72
	Width (cm)	***56.4***	***7.3***	***145.5***	***31.3***	***0.02***
Bushy-tailed Woodrat Used n = 6 Unused n = 15	Basal Area	6.5	1.9	5.6	1.7	0.73
	Canopy Closure	32.2	8.8	26.9	6.7	0.64
	% Bare	9.5	2.3	8.1	1.8	0.63
	% Grass	***12.8***	***3.7***	***25.8***	***3.9***	***0.02***
	% Gravel	15.7	4.5	22.3	3.4	0.27
	% Herb	21.8	4.4	20.8	5.0	0.88
	% Shrub	28.2	6.4	20.5	3.4	0.32
	% Other	12.3	5.7	3.1	1.2	0.17
	To clear zone (m)	2.5	1.1	2.3	1.1	0.88
	To forest (m)	11.33	6.7	20.2	8.5	0.42
	To road (m)	8.8	2.5	9.9	1.8	0.75
	To shrub (m)	3.0	1.0	7.5	3.4	0.22
	Height (cm)	72.3	19.9	96.4	11.5	0.32
	Length (cm)	***43.3***	***3.1***	***58.5***	***4.0***	***0.01***
	Width (cm)	121.5	68.8	107.5	15.8	0.85
Striped Skunk Used n = 6 Unused n = 15	Basal Area	7.3	2.0	4.5	1.6	0.34
	Canopy Closure	36.9	9.2	22.0	6.0	0.20
	% Bare	10.1	2.6	7.2	1.6	0.37
	% Grass	22.9	6.9	21.5	2.5	0.85
	% Gravel	16.3	4.8	23.4	3.1	0.23
	% Herb	29.3	7.7	14.9	2.0	0.10
	% Shrub	17.9	3.8	26.2	4.4	0.17
	% Other	5.2	2.7	6.2	2.9	0.81
	To clear zone (m)	3.6	1.6	1.4	0.8	0.24
	To forest (m)	22.4	13.7	14.1	4.8	0.58
	To road (m)	13.0	2.8	7.0	1.0	0.07
	To shrub (m)	10.3	5.6	3.2	0.8	0.24
	Height (cm)	69.9	10.6	104.2	14.6	0.07
	Length (cm)	50.2	4.6	57.2	4.7	0.30
	Width (cm)	79.6	17.7	135.5	34.5	0.17

* Indicates the probability that the sample means for used and unused structures could be derived from populations that with a much larger sample size would have the same mean. T-tests were conducted using SPSS ver. 9.0, 2 sided significance, equal variances not assumed are reported here.

Table 7.4 (continued). Habitat characteristics of 21 culverts where animals were detected during highway structure monitoring from June to October 1998. Habitat variables are described in table 7.1. Detection techniques included track plates, track beds, and automatic cameras.

	Habitat Characteristics	Used		Unused		t-test
		Mean	Std. Error	Mean	Std. Error	2-tailed significance*
Weasel	***Basal Area***	***11.3***	***1.9***	***3.7***	***1.3***	***0.01***
	Canopy Closure	***48.3***	***5.5***	***20.4***	***6.1***	***0.04***
	% Bare	11.5	2.4	7.3	1.7	0.18
	% Grass	***9.2***	***2.0***	***27.3***	***3.6***	***<0.01***
	% Gravel	14.3	4.8	22.8	3.2	0.18
	% Herb	26.3	3.9	19.0	5.0	0.26
Used n = 6	% Shrub	31.7	4.8	19.0	3.5	0.06
Unused n = 15	% Other	8.2	3.9	4.8	2.3	0.48
	To clear zone (m)	4.7	1.2	1.4	0.9	0.06
	To forest (m)	***2.2***	***0.7***	***23.9***	***8.4***	***0.02***
	To road (m)	11.5	2.2	8.8	1.8	0.36
	To shrub (m)	2.3	0.8	7.8	3.4	0.14
	Height (cm)	62.0	14.8	100.5	11.8	0.06
	Length (cm)	52.8	7.7	54.7	3.7	0.83
	Width (cm)	***62.3***	***14.7***	***131.2***	***28.3***	***0.04***
Raccoon	***Basal Area***	***1.8***	***0.7***	***7.1***	***1.5***	***0.01***
	Canopy Closure	***14.2***	***5.5***	***32.8***	***6.5***	***0.04***
	% Bare	***4.4***	***1.0***	***9.7***	***1.7***	***0.01***
	% Grass	***37.8***	***5.5***	***17.2***	***2.9***	***0.01***
	% Gravel	25.0	3.4	18.9	3.4	0.23
	% Herb	***12.4***	***2.5***	***23.8***	***4.7***	***0.04***
	% Shrub	***10.2***	***3.0***	***26.6***	***3.4***	***<0.01***
	% Other	11.2	6.1	4.1	1.7	0.32
Used n = 5	***To clear zone (m)***	***0.0***	***0.0***	***3.1***	***1.0***	***0.01***
Unused n = 16	***To forest (m)***	***35.2***	***7.3***	***12.2***	***7.6***	***0.05***
	To road (m)	***4.0***	***0.7***	***11.3***	***1.7***	***<0.01***
	To shrub (m)	8.6	3.1	5.5	3.1	0.49
	Height (cm)	127.6	26.6	77.6	8.8	0.14
	Length (cm)	52.2	6.2	54.8	4.0	0.73
	Width (cm)	215.6	72.0	79.0	9.2	0.13
Human	***Basal Area***	***1.7***	***1.5***	***6.8***	***1.5***	***0.01***
	Canopy Closure	17.2	6.6	31.0	6.3	0.16
	% Bare	9.0	1.7	8.3	1.7	0.79
	% Grass	32.2	6.7	19.7	3.4	0.16
	% Gravel	24.7	4.4	19.3	3.2	0.36
	% Herb	***12.7***	***1.0***	***23.1***	***4.5***	***0.04***
	% Shrub	13.5	6.8	24.8	3.3	0.20
	% Other	8.2	8.2	5.1	1.7	0.74
Used n = 4	***To clear zone (m)***	***0.0***	***0.0***	***2.9***	***1.0***	***0.01***
Unused n = 17	To forest (m)	50.7	26.0	9.9	3.6	0.21
	To road (m)	***5.0***	***1.1***	***10.6***	***1.7***	***0.01***
	To shrub (m)	15.7	12.1	4.0	1.2	0.40
	Height (cm)	128.3	18.6	80.2	10.6	0.07
	Length (cm)	43.7	6.1	56.6	3.7	0.12
	Width (cm)	220.5	85.5	85.9	13.4	0.21

* Indicates the probability that the sample means for used and unused structures could be derived from populations that with a much larger sample size would have the same mean. T-tests were conducted using SPSS ver. 9.0, 2 sided significance, equal variances not assumed are reported here.

Table 7.4 (continued). Habitat characteristics of 21 culverts where animals were detected during highway structure monitoring from June to October 1998. Habitat variables are described in table 7.1. Detection techniques included track plates, track beds, and automatic cameras.

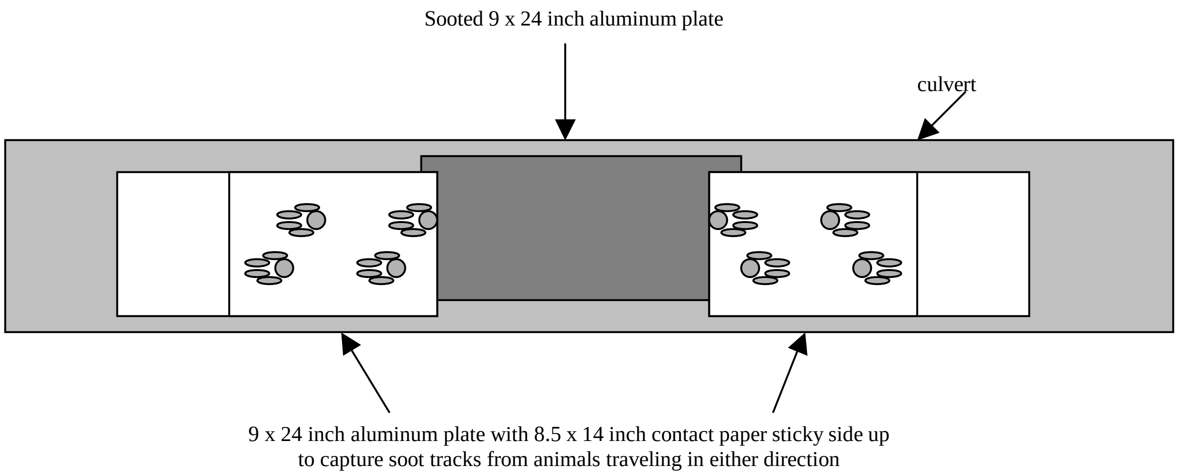
	Habitat Characteristics	Used		Unused		t-test 2-tailed significance*
		Mean	Std. Error	Mean	Std. Error	
Domestic Cat Used n = 4 Unused n = 17	***Basal Area***	***1.2***	***0.7***	***6.9***	***1.5***	***<0.01***
	Canopy Closure	***9.2***	***5.6***	***32.9***	***6.0***	***0.01***
	% Bare	6.5	1.5	8.9	1.7	0.32
	% Grass	***54.2***	***7.0***	***17.3***	***2.5***	***0.03***
	% Gravel	29.0	1.7	18.3	3.2	0.09
	% Herb	10.2	2.6	23.6	4.4	0.08
	% Shrub	***9.2***	***3.7***	***25.8***	***3.3***	***0.01***
	% Other	2.0	2.0	6.6	2.4	0.16
	To clear zone (m)	***0.0***	***0.0***	***2.9***	***1.0***	***0.01***
	To forest (m)	50.0	26.1	10.1	3.4	0.22
	To road (m)	***5.5***	***0.6***	***10.5***	***1.7***	***0.01***
	To shrub (m)	20.2	11.2	2.9	0.7	0.22
	Height (cm)	112.5	15.5	84.1	11.6	0.19
	Length (cm)	57.7	7.9	53.3	3.8	0.64
	Width (cm)	138.0	27.4	105.3	25.9	0.41
Snowshoe Hare Used n = 2 Unused n = 19	Basal Area	11.5	8.5	5.3	1.2	0.60
	Canopy Closure	39.0	30.0	27.3	5.4	0.76
	% Bare	***13.0***	***0.0***	***8.0***	***1.5***	***0.01***
	% Grass	24.0	6.0	21.9	3.5	0.79
	% Gravel	21.5	16.5	20.3	2.8	0.95
	% Herb	22.5	12.5	20.9	4.0	0.92
	% Shrub	14.0	9.0	23.6	3.2	0.47
	% Other	6.5	1.5	5.7	2.2	0.77
	To clear zone (m)	3.0	3.0	2.3	0.9	0.85
	To forest (m)	3.0	3.0	19.2	6.9	0.05
	To road (m)	9.5	0.5	9.6	1.6	0.96
	To shrub (m)	3.5	1.5	6.5	2.7	0.35
	Height (cm)	***127.5***	***7.5***	***85.5***	***10.7***	***0.01***
	Length (cm)	62.0	22.0	53.4	3.2	0.76
	Width (cm)	127.5	7.5	109.8	23.8	0.49

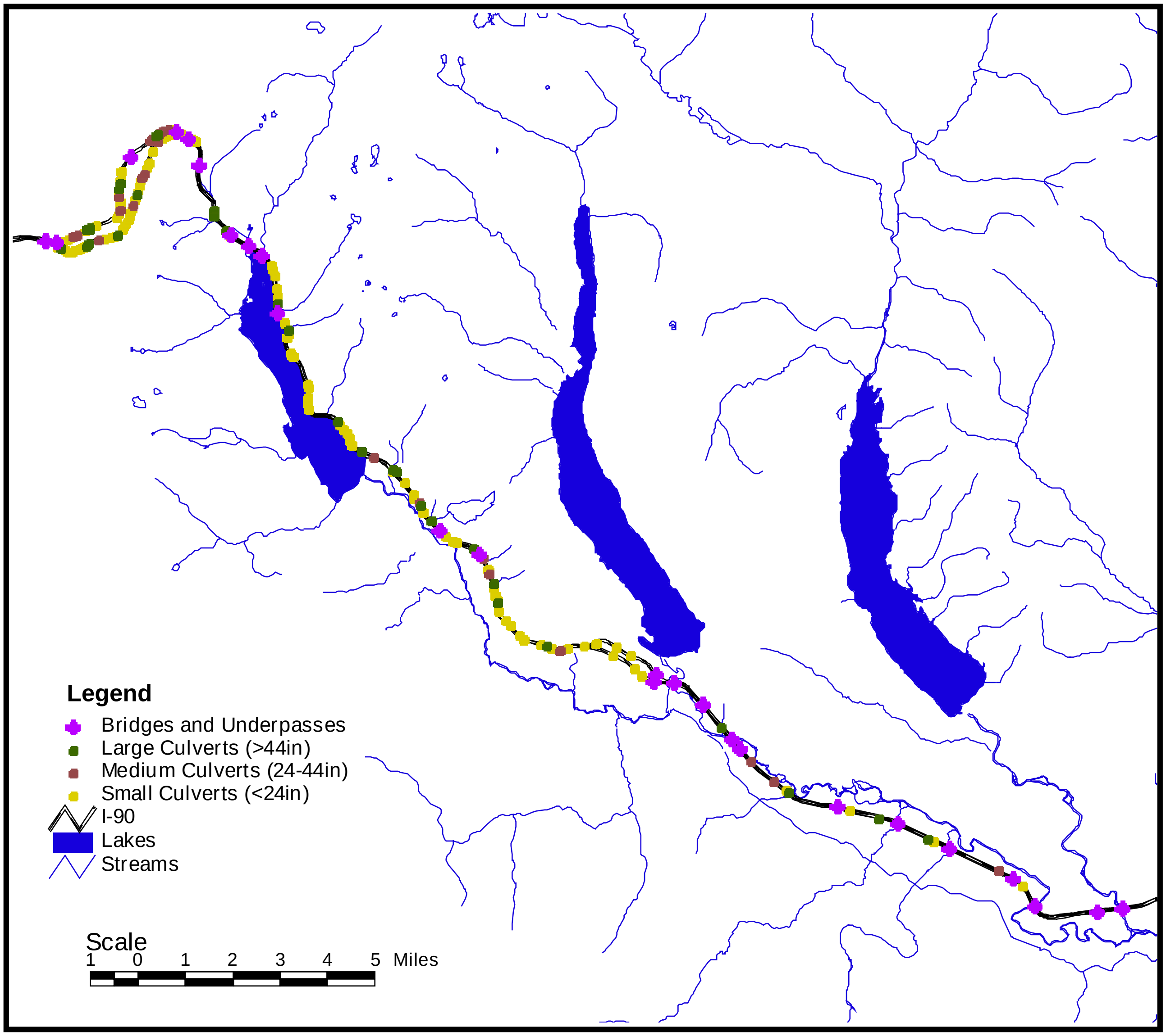
* Indicates the probability that the sample means for used and unused structures could be derived from populations that with a much larger sample size would have the same mean. T-tests were conducted using SPSS ver. 9.0, 2 sided significance, equal variances not assumed are reported here.

Table 7.5. Results of small mammal trapping at I-90 drainage culverts, August 1999. Trapping was conducted at 15 culverts (a trapping station at each end of the culvert) for a total of 884 trap nights (443.5 nights in culverts and 440.5 nights outside of culverts).

Species	**Inside Culverts**			**Outside Culverts**		
	Total Captures	**Captures Per 100 trap-nights**	**Number of Stations**	**Total Captures**	**Captures Per 100 trap-nights**	**Number of Stations**
All Species	68	15.3	20	139	31.6	29
Peromyscus species (total)	56	12.6	17	117	26.6	29
Forest Deer Mouse (*P. Keenii*)	31	7.0	14	62	14.1	24
Deer Mouse (*P. maniculatus*)	25	5.6	12	55	12.5	22
Tamias species (Total)	4	0.9	3	13	3.0	5
Microtus species (total)	3	0.7	2	2	0.5	2
Short-tailed Weasel	2	0.5	2	2	0.5	2
Yellow-pine Chipmunk	2	0.5	2	10	2.3	4
Townsend's Chipmunk	2	0.5	2	3	0.7	3
Western Jumping Mouse	2	0.5	2	3	0.7	3
Long-tailed Vole	2	0.5	1	1	0.2	1
Townsend's Vole	1	0.2	1	1	0.2	1
Bushy-tailed Woodrat	1	0.2	1	1	0.2	1
Red-backed Vole	0	0.0	0	1	0.2	1

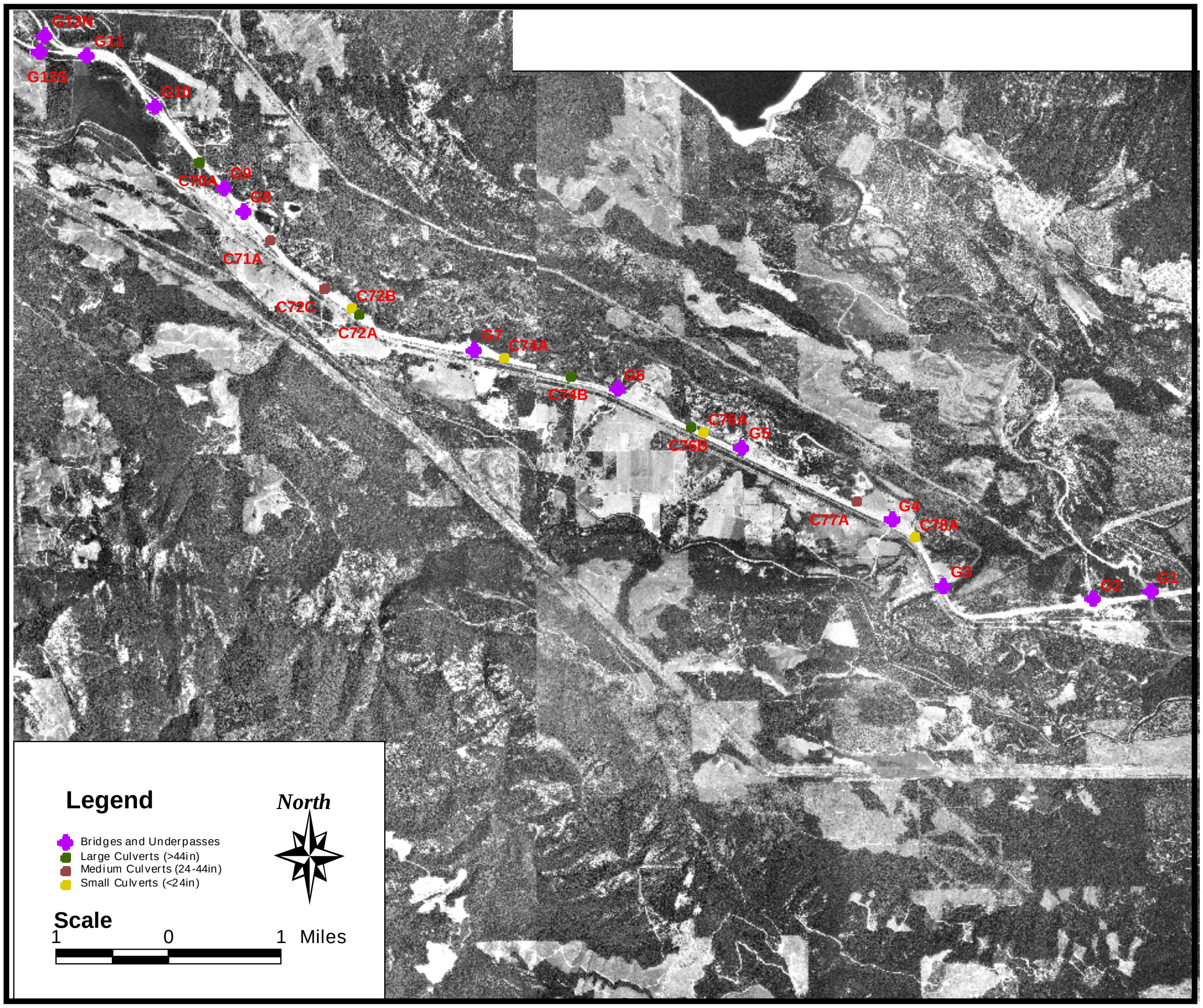
Figure 7.1. Track plate configuration used for monitoring culverts less than 1 meter diameter.





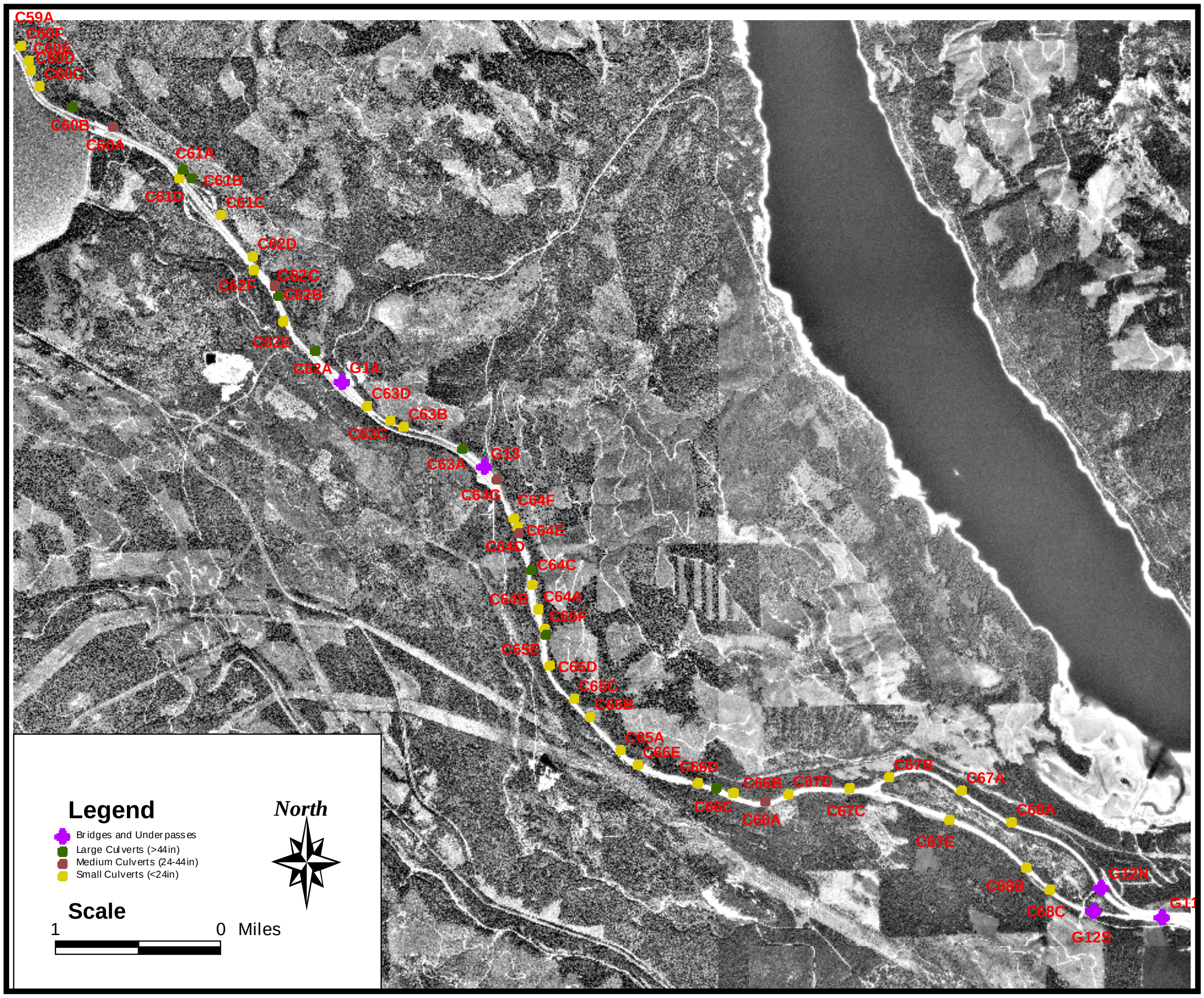
Highway Structures Along I-90

Figure 7.2. Highway structures inventoried along I-90 during the I-90 Snoqualmie Pass Wildlife Habitat Linkage Assessment Project.



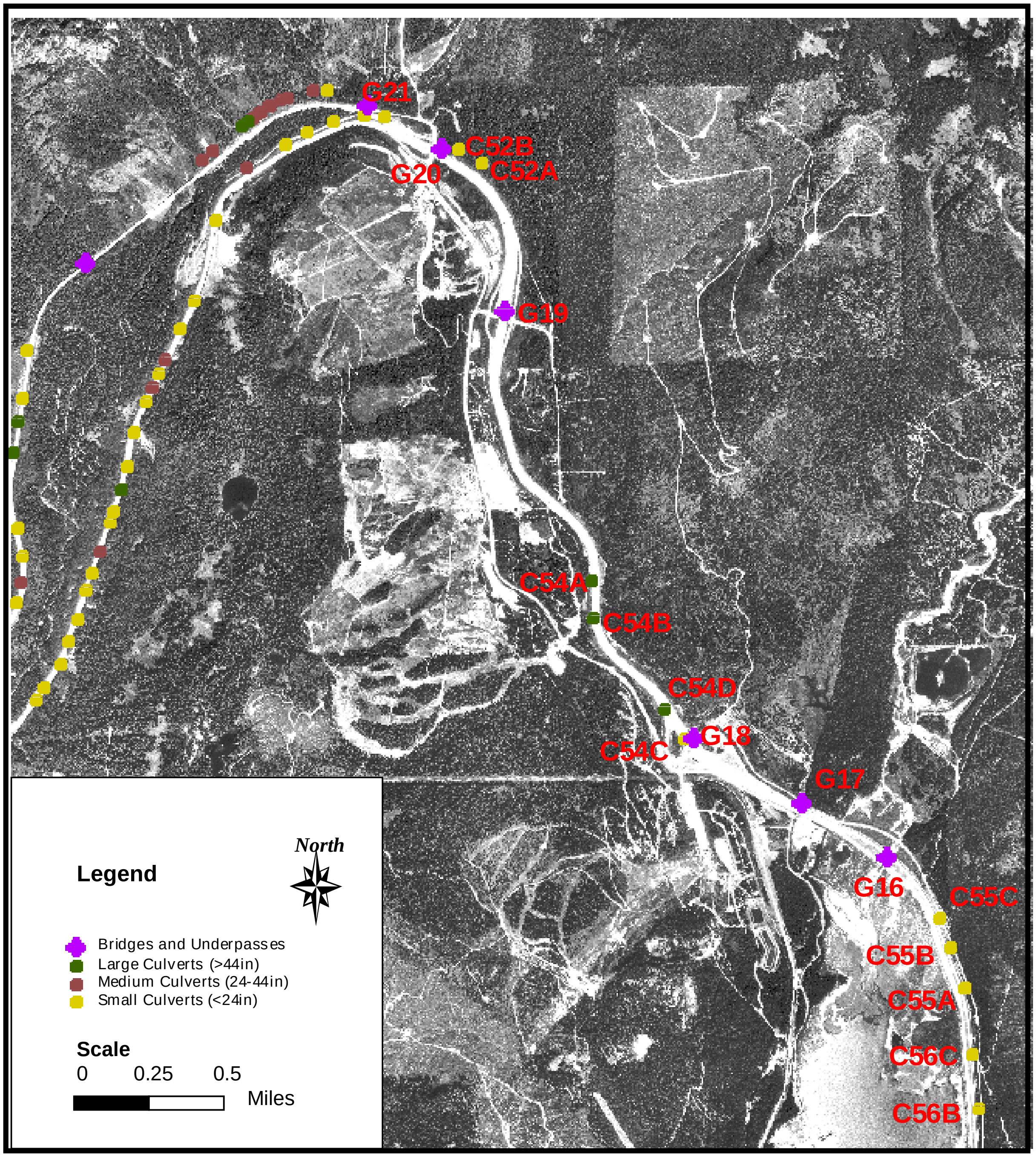
Section 1 Highway Structures

Figure 7.3. Highway structures in section 1 of I-90.



Sections 2, 3, and 4 Highway Structures

Figure 7.4. Highway structures in sections 2, 3 and 4 of I-90.

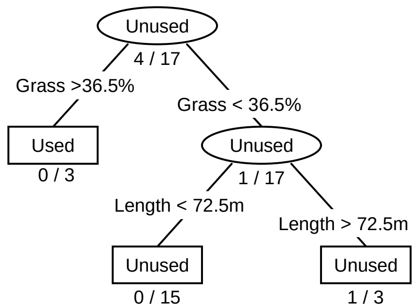


Section 5 Highway Structures

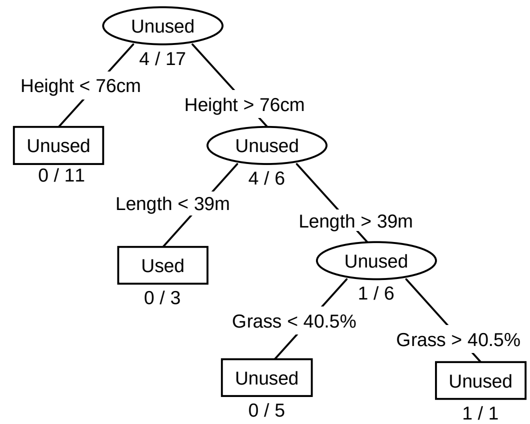
Figure 7.5. Highway structures in section 5 of I-90.

Domestic Species

Domestic Cat

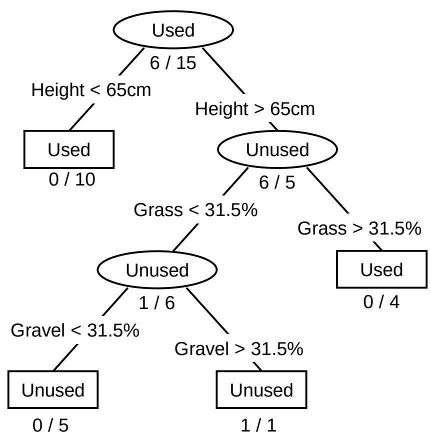


Humans

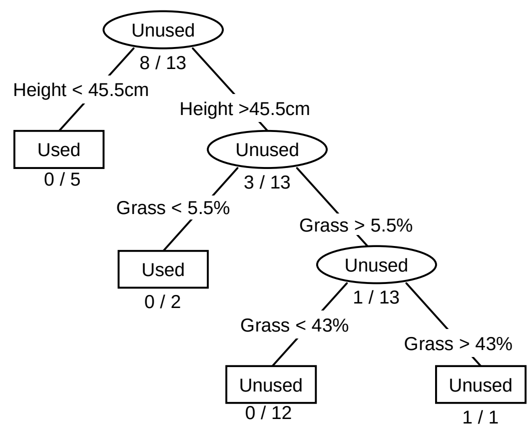


Rodents

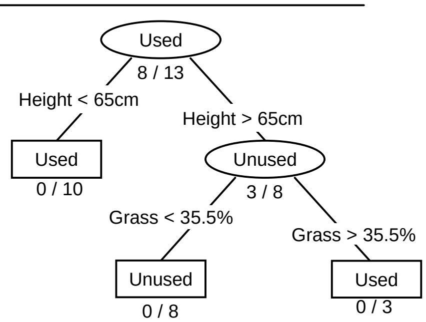
Chipmunks



Jumping Mouse



Mice



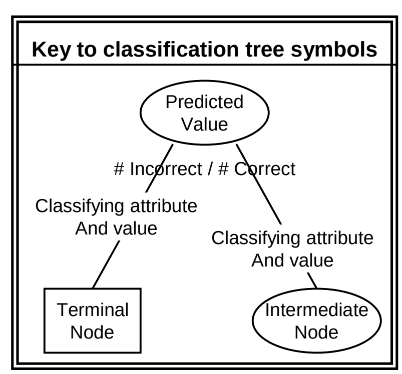
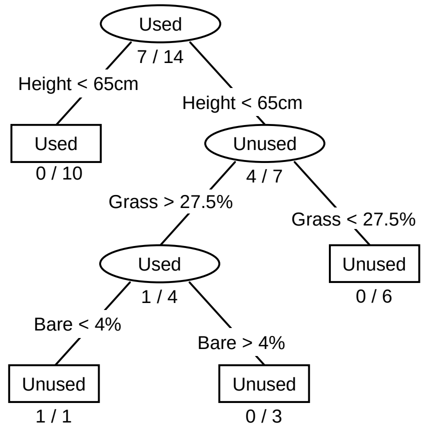


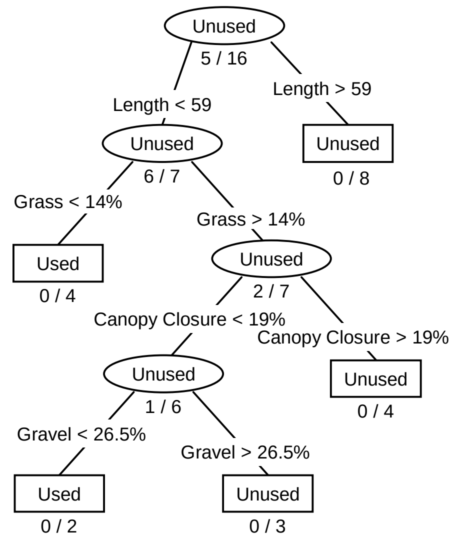
Figure 7.6. Classification trees for distinguishing highway structures used and unused by wildlife from highway structure monitoring conducted during summer and fall 1998. Structure attributes are described in table 7.1.

Rodents (cont.)

Douglas Squirrel

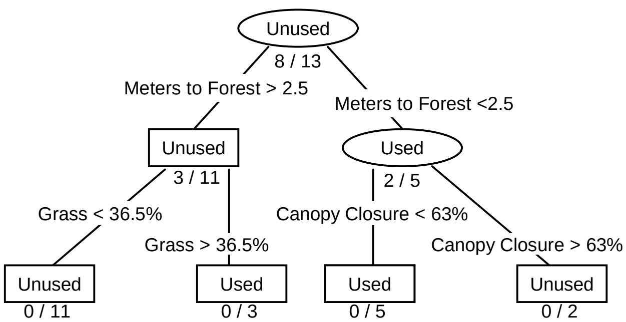


Bushy-tailed Woodrat

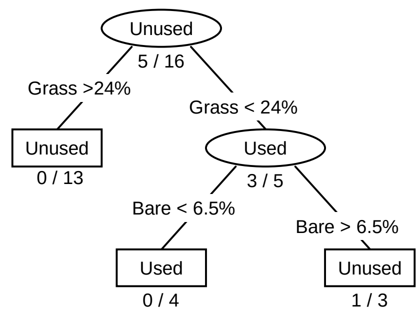


Carnivores

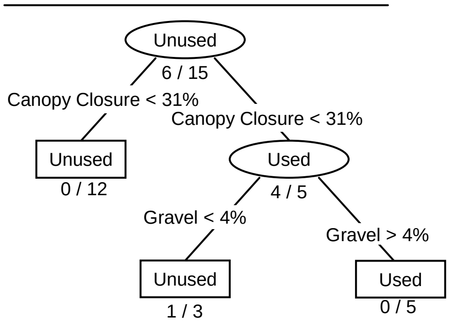
Striped Skunk



Raccoon



Weasel



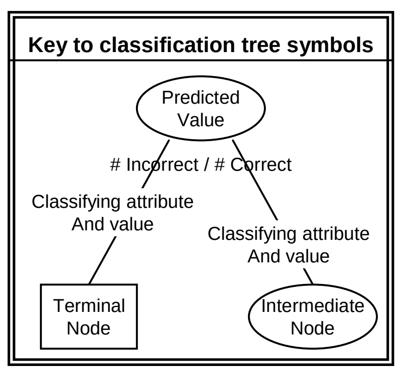
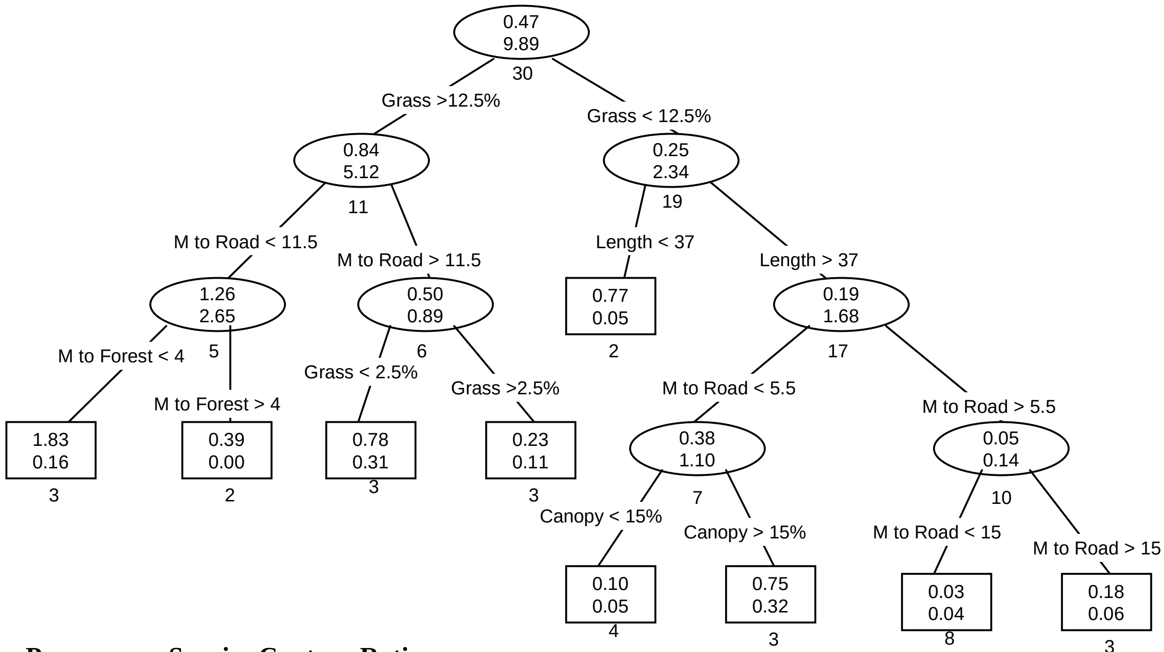
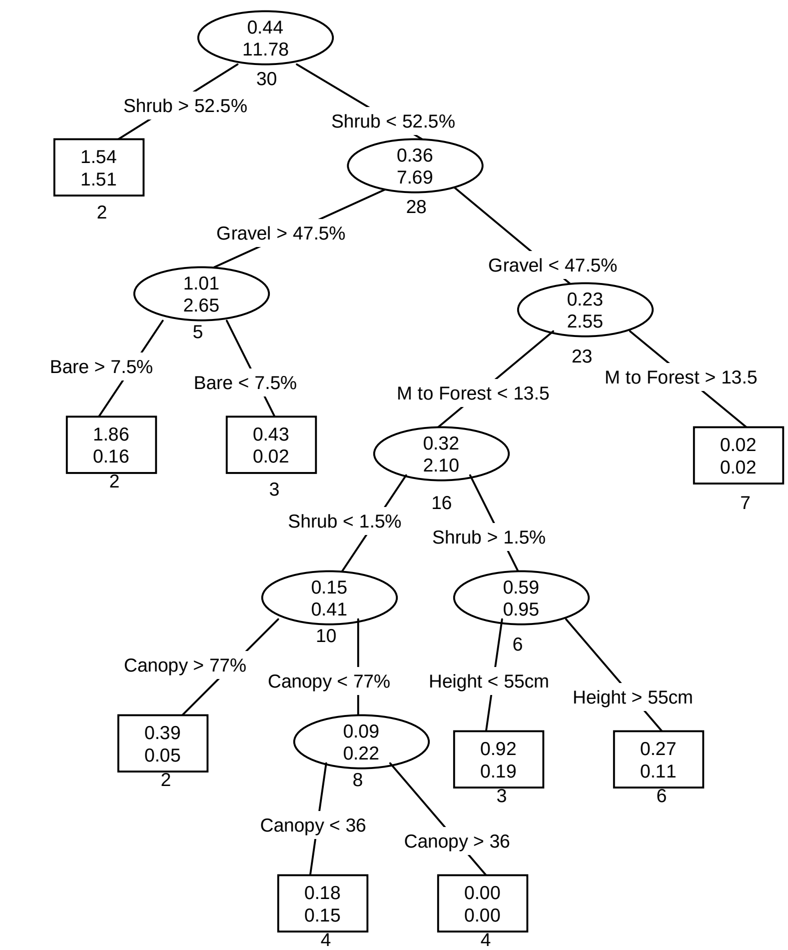


Figure 7.6 (continued). Classification trees for distinguishing highway structures used and unused by wildlife from highway structure monitoring conducted during summer and fall 1998. Structure attributes are described in table 7.1.

Total Capture Ratio



Peromyscus Species Capture Ratio



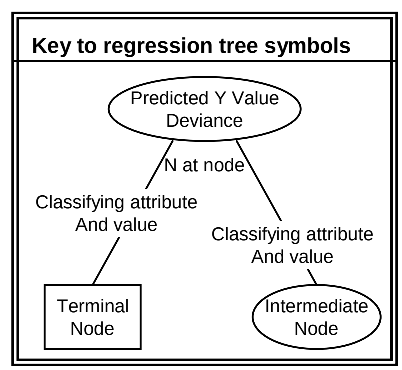


Figure 7.7. Regression trees for predicting small mammal use of drainage culverts from small mammal trapping conducted along Interstate 90 in August 1999. Structure attributes are described in table 7.1.

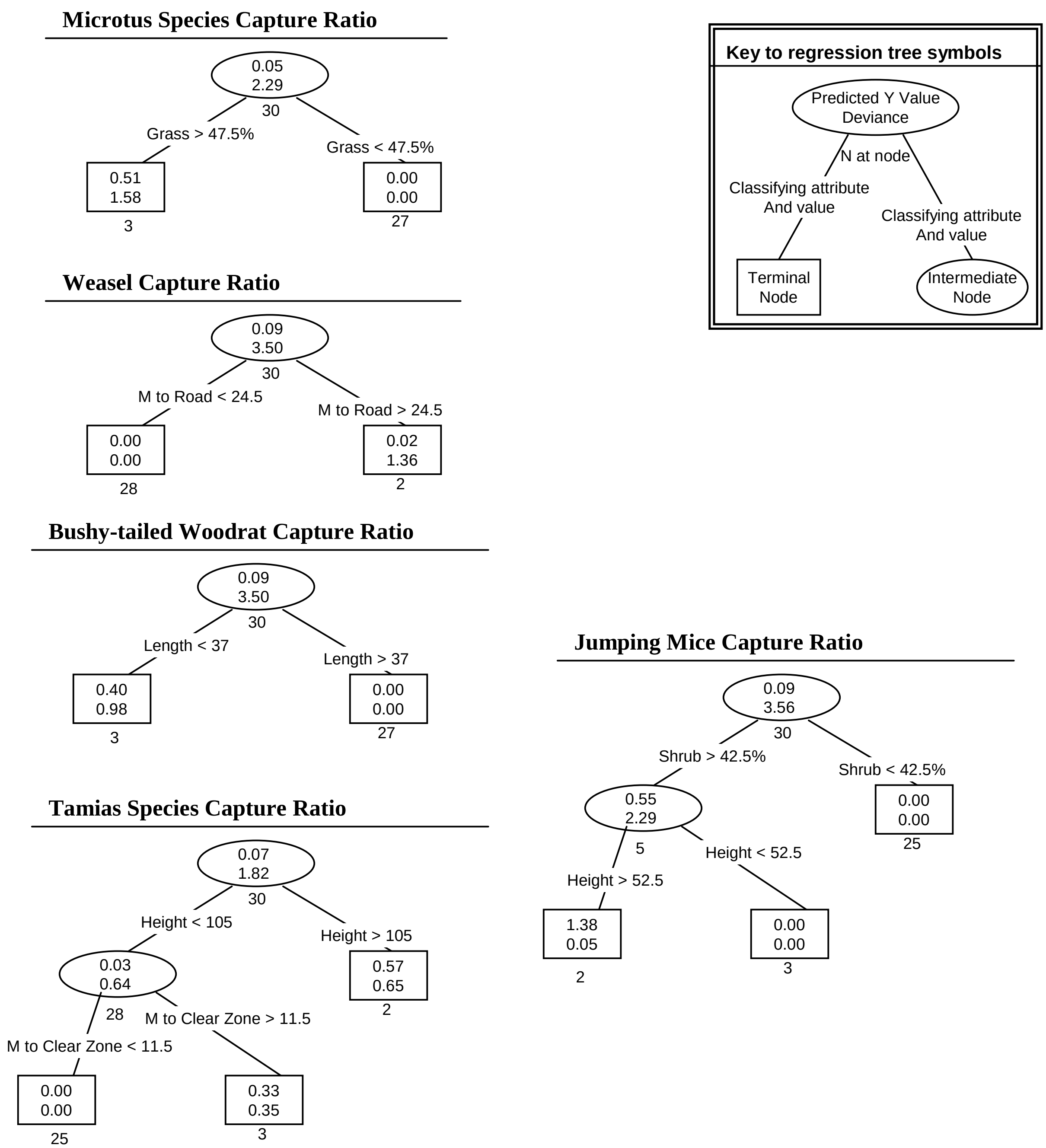


Figure 7.7 (continued). Regression trees for predicting small mammal use of drainage culverts from small mammal trapping conducted along Interstate 90 in August 1999. Structure attributes are described in table 7.1.

8) Discussion

8.1) Introduction

Three broad potential connectivity areas were identified in the I-90 Land Exchange EIS these were called the Cascade Crest, Keechelus Ridge, and Easton Ridge corridors (USDA Forest Service 1999). Based on the results of this study, we have identified 3 to 7 areas that appear to have greater landscape permeability relative to adjacent areas in the I-90 Snoqualmie Pass corridor (figure 8.1). Areas that we have identified as having greater landscape permeability roughly correspond to those identified in the I-90 Land Exchange EIS. These areas are defined by large-scale landscape features including lakes and rugged ridges and roughly correspond to combinations of the highway sections identified in this study. Due to the substantial elevation and precipitation gradient along I-90, these areas provide different habitat characteristics that support different communities of organisms (USDA Forest Service 1999). Maintenance and enhancement of landscape permeability will need to address issues of habitat connectivity at a landscape scale and provide animals with opportunities to cross the highway at appropriate locations. In the following sections, we will discuss the combined results of the project components and other available information to identify areas of existing and potential connectivity for wildlife movement.

8.2) Snoqualmie Pass – Section 5

This area corresponds to the Cascade Crest movement corridor described in the I-90 Land Exchange EIS (USDA Forest Service 1999). Species of concern in this area include those species associated with higher elevation late successional forest and montane habitats, including American marten, wolverine, and mountain goat. Primary factors affecting wildlife habitat connectivity here include ski resort and residential developments, rugged topography (including the small but steep Cole Creek gorge), and the deeply incised east-bound lanes between mileposts 49 and 52 just west of Snoqualmie Summit. Despite these features, there are 3 potential connectivity areas along this section of highway.

<u>Airplane Curve (milepost 51-51.5)</u>

Despite the fact that steep embankments and retaining walls on the east-bound lanes are likely to prevent wildlife movement through this area, Airplane Curve, near milepost 51, has excellent proximity of late successional forest. Connectivity modeling results showed the best late successional habitat connectivity in the vicinity of the Cascade Crest for high and moderate mobility guilds to be in this area. Highway structures provide connectivity through the westbound lanes in this area but not the east bound lanes. West of Snoqualmie Summit, the bridge over the South Fork of the Snoqualmie River and the viaduct over Denny Creek provide good opportunities for animal passage from the north into the forested median. However, the deeply incised roadway with steep embankments and high retaining walls for the east-bound lanes between mileposts 49 and 52 do not provide animal crossing opportunities. Two camera stations and a snow tracking detection of American marten within 0.25 miles of the highway at airplane curve indicate the potential importance of this area for late successional species found at higher elevations.

The corner of sections 10 and 16, T22N, R11E (milepost 54-54.5)

Two sections under Forest Service ownership on the east side of the pass (T22N, R11E, sections 10 and 16) have remained free of residential development and have retained some late successional forest cover. The corners of these sections meet near milepost 54. In the landscape linkage modeling, the common corner of sections 10 and 16 is predicted to provide the best connectivity for low mobility species along the Cascade Crest. Bear detections at 2 camera stations in the southern portion of this corridor and a bobcat detection on the north side indicate potential for use. One crossing by coyote was recorded during snow tracking near milepost 54. There is, however, a distinct break in road-kill distribution around milepost 54 correlated with the very rugged topography of Coal Creek The steep stream banks are likely to prevent frequent ungulate movement through this area. Two large box culverts (C54B and C54C) that provide flow for Coal Creek beneath I-90 were monitored in this area. On Sept. 28, 1998 an American marten was photographed passing through structure 54B. Bushy-tailed woodrats were also detected in this structure. Hanging ledges on the downstream ends of these culverts and the rugged topography of the adjacent landscape may be preventing additional use of these structures.

Gold Creek (mp 55-56)

The area along Gold Creek and the north end of Keechelus Lake probably has the best existing connectivity for animal movement near Snoqualmie Pass. The north end of Keechelus Lake in the vicinity of Gold Creek is an area of high ungulate road-kill density relative to the rest of the highway in the vicinity of Snoqualmie Pass. Animals hit on the road here are probably moving between the Gold Creek valley, the seasonally de-watered portions of the Keechelus Lake bed, and the west shore of the lake. Highway structures that may be providing for animal movement in this area include the bridges over Coal and Gold Creeks just east of milepost 55. Humans and deer were documented using these structures for highway crossing during structure monitoring. Bobcat and northern flying squirrel were recorded at automatic camera stations on both sides of the highway in this area. A relatively high density of coyote detections was recorded during snow tracking surveys along the west shore of Keechelus Lake within 0.25 miles of the highway. Washington State Parks personnel living at the Hyak Sno-Park reported that they had observed carnivore (bobcat, coyote, and mountain lion) sign indicating movement along the Coal Creek riparian strip leading to the bridge (G17) near the WSDOT Hyak maintenance facility.

8.3) Keechelus South and Amabalis Mtn. – sections 3 & 4

This area corresponds to the Keechelus Ridge wildlife movement corridor identified in the I-90 Land Exchange EIS (USDA Forest Service 1999). As with much of the rest of the study area, topography and human disturbance are the primary factors driving wildlife movement in the Keechelus Ridge area. Keechelus Lake and Amabalis Mountain appear to constrain most movement to the area between mileposts 61 and 64. Human activity centered on the Crystal Springs Campground, forest roads 49 and 54, and the Price Creek Sno-Park appear to further concentrate animal movement. Connectivity modeling results in this area are skewed toward the east by the dominance of the Easton Hill corridor, though model runs for high mobility species show some permeability for animals moving along the south edge of Keechelus Lake relative to the adjacent landscape. Coyote, elk, northern flying squirrel, snowshoe hare, bobcat, mule deer, and black bear were all frequently detected here during automatic camera surveys, indicating that a variety of species, including carnivores, do get to the highway in this area.

Coyote were detected significantly more often than average along snow tracking transects in the Keechelus south section. Thirteen highway crossings by coyote and 3 by bobcat were recorded along this section. Only the Easton Hill area had more highway crossings recorded during snow tracking. Out of these 16 crossings, 13 occurred in 2 clusters east and west of the Stampede Pass exit (mileposts 61.9 to 62.5 and 63.2 to 63.8, figure 6.5). Cougar tracks were also detected while checking camera station 9920 just southwest of Crystal Springs Campground (near milepost 62.5) on June 16, 1999 and a road-killed cougar was documented at milepost 62 on October 15, 1999. These were the only detections of cougar near the highway during this study.

Road-kill locations in this area were concentrated between the south end of Keechelus Lake and milepost 63. The area around milepost 61 has the second highest concentration of road-kills in the study area. Animals are probably channeled into this area by the lake, relatively secure forested habitat just southeast of the dam, and human disturbance associated with the Crystal Springs Campground and forest roads 54 and 49.

Existing structures that might provide opportunities for animal movement in this area include the highway overpasses at exits 63 and 64. These structures were not monitored because of risk of loss of equipment, heavy traffic, and inadequate opportunities for camera placement. We expect that relatively heavy human traffic on these structures is likely to preclude extensive use of these structures by sensitive wildlife. Four box culverts were monitored in this section: 1) Price Creek (C61A, milepost 61.5), monitored but nothing detected, 2) Swamp Creek (C62A, milepost 62.7), chipmunk, river otter, and raccoon were detected using this structure, 3) C62B near milepost 62, chipmunk was detected in this structure, and 4) C63A milepost 63.8, opossum, snowshoe hare, and weasel detected.

The substantial gap in road-kills between mileposts 64 and 67 indicates the relative impermeability of this area to ungulate movement. This is the steep southern slope of Amabalis Mountain. I-90 is deeply incised into the hillside in this area with substantial cut slopes on the north side of the highway and steep embankments on the south side. There is a Jersey barrier throughout the median of this section as well as on one or both shoulders through much of this section. Carnivores are, however, present in the area. Coyote and bobcat were regularly detected during snow tracking and camera surveys in this area, and 3 coyote crossings were recorded during snow tracking (1 near the Cabin Creek exit at milepost 64.2 and 2 near milepost 65, figure 6.4). Black bear were also frequently detected at automatic camera stations in this area.

Three large box culverts are present in section 3. They are; 1) Cedar Creek (C64C milepost 64.5) where humans and weasel were detected, 2) C65E where snowshoe hare, weasel, and squirrel were detected, and 3) C66C where there were no animal detections during monitoring.

8.4) Easton Hill – section 2

In the eastern portion of the study area, topography and human disturbance appear to channel animals onto the east slope of Amabalis Mountain at Easton Hill between mileposts 67 and 69. This area was identified during the landscape linkage modeling as the most permeable area for late successional species moving through the study area. Landscape linkage modeling results for high and moderate mobility species were dominated by forest connectivity patterns extending from source habitats in the Waptus Lake portion of the Alpine Lakes Wilderness, south along Kachess Ridge and the Silver Creek drainage, crossing I-90 at Easton Hill and connecting to forested habitats in the Cabin Creek drainage, Goat Peak, Blaze Ridge, and source habitats southwest of the Naches River in the Norse Peak Wilderness. In addition to landscape-scale habitat connectivity, the widely divided highway and forested median contribute to highway permeability in this area.

This area had the highest road-kill density for elk in the study area. Road-kills of elk were concentrated toward the top of Easton Hill around milepost 68. Deer were also frequently hit in this area, but not substantially more often than at lower elevations in the Yakima River Valley.

Dog, northern flying squirrel, bobcat, deer, and black bear were all relatively frequently detected at automatic camera stations in this area. Dog detections were clustered in the vicinity of Kachess Dam and Easton State Park, providing some indication of the level of human disturbance closer to the residential and recreational development around the town of Easton. Northern flying squirrel, bobcat, and deer were detected at both the east and west ends of Easton Hill. Black bear detections were concentrated in the western portion of the section.

Highway structures that may provide opportunities for large animal movement through this area are the 2 underpasses for the access road to the private timber lands south of the highway at milepost 69 (structure G12). These structures were monitored with cameras from August 6 to September 1, 1998. No animal detections were recorded. Four smaller culverts were monitored in this area with use by chipmunks, striped skunk, mice, squirrels, and pacific jumping mice.

Snow tracking surveys highlighted the relative permeability of this area for winter animal movement. Coyote, bobcat, and elk were all detected significantly more often at Easton Hill than average across the study area. Thirty-eight of the 67 highway crossings recorded during snow tracking occurred in the Easton Hill area. Twenty-nine coyote, and 9 bobcat crossings were recorded in this area. During 1999, this was the only area where bobcat were recorded crossing the highway when it was open to traffic. Crossing locations were grouped in 6 clusters along Easton Hill (figure 6.3); 1) west bound lanes at milepost 67.5 to 67.9 where 3 coyote and 2 bobcat were recorded crossing in 2000 and 3 coyote and 1 bobcat were recorded crossing in 1999, 2) east bound lanes at mile post 68.0 to 68.3

where 3 coyote crossings were recorded in 2000 and 2 coyote and 1 bobcat crossings were recorded in 1999, 3) west bound lanes at milepost 68.2 to 68.3 where 2 coyote crossings were recorded in 2000 and 1 coyote crossing was recorded in 1999, 4) east bound lanes at milepost 68.5 to 68.7 where 3 coyote and 1 bobcat were recorded crossing in 1999, 5) west bound lanes at milepost 68.6 to 68.8 where 2 coyote crossings were recorded in 2000 and 1 coyote crossing was recorded in 1999, and 6) east bound lanes at milepost 68.9 to 69.0 where 5 coyote crossings were recorded in 1999 and 1 bobcat crossing was recorded in 2000.

Continuing development may limit the value of this area for wildlife connectivity over time. A sub-division on the north side of the highway at milepost 69 has been developed, and another sub-division on the south side of the highway just west of Easton State Park has been platted and utility lines were installed in the summer of 1999. In addition, recent timber harvest just south of Easton Hill at milepost 68 may have compromised the value of this area for wildlife movement. The forest strip on the west side of Easton Lake in the state park provides some connectivity, though high levels of human recreation use may limit the value of this area for movement of sensitive wildlife.

8.5) Yakima River Valley – section 1

Human disturbance, development, and forest cover associated with riparian strips are likely to be directing animal movement in the relatively flat Yakima River Valley. High levels of human development and sparse forest cover in this area are expected to contribute to a low level of landscape permeability. This area corresponds to the Easton Ridge wildlife movement corridor identified in the I-90 Land Exchange EIS. Lower levels of development and the presence of scattered forest cover may provide for animal movement in the area between Tucker Creek and Big Creek (mileposts 73 to 75). Floberg (1998) identified 3 potential wildlife movement corridors in this area. His assessment focused on the area just west of Lavender Lake (milepost 73.5). He also identified the Cle Elum River and the Kachess River as potential connectivity areas. During the winter of 2000 we refocused our snow tracking efforts in this area to document animal use of the area just west of Lavender Lake (transects 1CN and 1CS, figure 6.2).

Our connectivity modeling identified the Yakima River Valley bottom as a barrier to movement for high and moderate mobility animals because of high road and building density. Areas of the narrowest barrier for high and moderate mobility species, and moderate connectivity for low mobility late successional species, were identified at Tucker Creek, west of Lavender Lake (milepost 63.5), and the forested strip east of Lavender Lake (milepost 64.5).

Road-kill locations are relatively evenly distributed from milepost 69 through 74. The drop in road-kill density from mile 75 to 79 corresponds to the heavily developed area on the north side of this portion of highway. There is a minor peak in road-kill at elk meadows, just west of the bridge over the Yakima River, and a very strong peak near the Cle Elum River at mile 81. Road-kills from mile 71 east are predominantly of deer. The peak in road-kill density at the Cle Elum River represents the area of highest road-kill density in the study area.

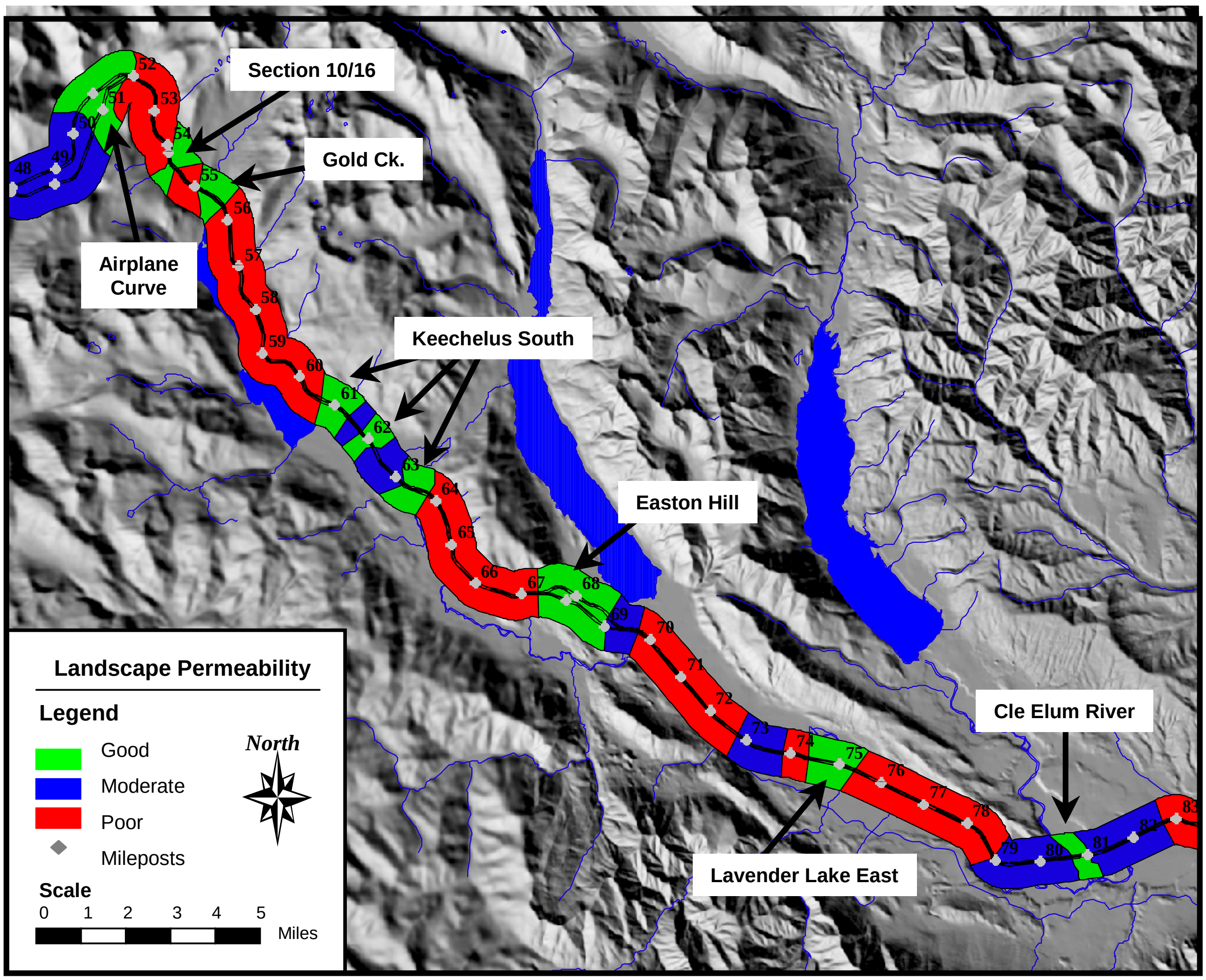
Animals frequently detected during automatic camera surveys in this section were elk, deer, and Douglas squirrel. These 3 species were detected throughout the section. Stripped skunk only in the Yakima Valley and in the lower portion of Easton Hill. Coyote and bobcat were detected less frequently in this area than in other highway sections. Black bear were not detected at any camera stations within a mile of the highway in this section, though bear were detected nearby, at a camera station at the top of Easton Ridge.

Existing highway structures that could provide animal passage in this area include bridges over the Yakima River at Easton (G9, milepost 71), Big Creek (G6, milepost 75), Little Creek (G5, milepost 76.5), the Yakima River at Sun Country (G3, milepost 79), and the Cle Elum River (G1, milepost 81). All of these structures provide stream banks that could be navigated by large animals. Levels of human disturbance at these structures are generally high. These places are popular for summer recreation (swimming, fishing, and campfires). Graffiti, beer bottles, and fire rings are often present beneath these structures. The bridge over the Cle Elum River at milepost 81 is the only structure that does not get extensive human use. These structures were monitored during 1998 and 1999. Species detected using these structures included cats, dogs, humans, porcupine, striped skunk, mice, weasel, deer, raccoon, and squirrel. No carnivores larger than raccoon were detected in these structures (in spite of the known presence of coyote and bobcat in the area), and their utility to species sensitive to human disturbance is expected to be low. The bridge over the Kachess River at Easton State Park (milepost 69) was not considered to be suitable for animal movement because of the lack of streamside travel routes under the bridge. Passage under this bridge without swimming is only possible at very low water levels.

Four large culverts that may be used by animals for crossing are present in this area (C70A, C72A, C74B, and C76B). Domestic cat, chipmunk, striped skunk, mice and raccoon were recorded in structures C72A and C74B. Only domestic cat were recorded in C76B. We attempted to monitor C70A but the camera was vandalized before any data was collected. These structures also receive substantial human use by local residents crossing I-90.

Coyote, elk, porcupine, bobcat, stripped skunk, deer, raccoon, domestic cat, dog, and humans were detected during snow tracking surveys in this area. Striped skunk and raccoon are associated with low elevation developed landscapes and, during tracking surveys, were only detected in this area. Detection rates of coyote and bobcat were significantly lower in the Yakima Valley than average across the study area. Detection rates were particularly low west of Lavender Lake where coyote were detected during winter 2000 on only 1 of 5 surveys of transect 1CS, compared to coyote detections during 3 of 5 surveys on the adjacent transect, 1AS. No coyote detections were documented north of the highway on transects 1CN or 1AN during winter 2000.

Highway crossings recorded during snow tracking in the Yakima Valley were concentrated in the area between Lavender Lake and Big Creek (milepost 74 to 75.5, figure 6.2). Raccoon were recorded crossing the highway in this area 5 times, including a crossing under the bridge at Big Creek. One bobcat crossed approximately 1 mile east of Lavender Lake (milepost 75) on February 24, 1999 while the highway was closed for avalanche control, and a coyote crossed in the same area on January 7, 2000. These were the only crossings by bobcat or coyote recorded along tracking transects in the Yakima Valley. One additional coyote crossing was recorded in 1999 during opportunistic tracking near the Nelson Siding Road exit (milepost 77.9).



I-90 Relative Landscape Permeability

Figure 8.1. Relative landscape permeability for high and moderate mobility wildlife along I-90 on the east side of Snoqualmie Pass.

9) Strategies for Managing Landscape Permeability

9.1) Introduction

Modification of highway characteristics and implementation of crossing structures to provide opportunities for animal passage across highway corridors has been undertaken in a number of areas (e.g. Evink et al. 1999, 1998, 1996). Three primary types of structures have been implemented to provide animals opportunities to cross highways. These include underpasses, bridges and viaducts, and overpasses. In most installations of animal crossing structures, fences that direct animal movement to the crossing structure and prevent animals from moving out onto the road are a critical component of the installation. In this section we will identify areas where habitat connectivity could be enhanced, and strategies to achieve this goal. The authors of this report are not highway engineers. Obviously any specific structures to be implemented need to be designed with the input of highway engineers, wildlife biologists, adjacent land owners, and land management agencies. The following comments are broad suggestions of suitable areas to address to enhance landscape permeability and potential approaches to improving permeability in those areas.

9.2) Snoqualmie Pass

Three areas of potential connectivity exist in the vicinity of Snoqualmie Pass (between mileposts 49 and 56). We will discuss each area separately.

<u>Airplane Curve</u>

This area has excellent connectivity between larger patches of late successional habitat, however animal movement between these patches is blocked by the steep embankments, high retaining walls, and 4 lane configuration of the east bound lanes of I-90 between milepost 49 and 51.5. Connectivity beneath the west bound lanes is provided by the bridge over the South Fork of the Snoqualmie River and the viaduct over Denny Creek Good connectivity of late successional forest habitat could be provided if there were an opportunity for animals to cross the east bound lanes of I-90 in the vicinity of milepost 51. This area is under Forest Service ownership. Future conditions in this area may change with development at the ski areas, but the western slope of the pass in the vicinity of Airplane Curve should not be substantially impacted.

This potential connectivity area corresponds to an avalanche zone. A combination avalanche shed / wildlife passage structure could provide opportunities for movement for montane species including American marten, wolverine, and mountain goat. The steep slope of an avalanche shed structure may not provide effective passage for species not adapted to steep mountainous terrain, however target species in this area are adapted to such terrain. Steep slopes and the deeply incised roadway preclude installation of underpasses in this area. Fencing usually associated with wildlife crossing structures may not be necessary in this area because the steep roadside embankments and retaining walls prevent animal movement onto the road. Installation of fencing in this area would also be impractical because of heavy snow loads and damage to the fence.

Section 10 / 16

Two sections under Forest Service ownership on the east side of the pass (T22N, R11E, sections 10 and 16) have retained good connectivity of late successional habitat on both sides of the highway. Late successional habitat on the north side of the highway is, however, fragmented and the habitat on the south side of the highway is a narrow strip between ski area developments. The southern portion of this corridor has also been proposed for ski slope development (Snoqualmie Pass Master Development Plan 1999). Increasing levels of recreational use and residential development associated with the ski areas could impact the value of this area for late successional habitat connectivity especially for species sensitive to human disturbance such as wolverine. Rugged topography of the Coal Creek gorge and embankments associated with the highway probably limit the value of this area for species not adapted to rugged landscapes.

Structural modification of the highway in this area could focus on the Coal Creek crossings beneath I-90. Replacement of the box culverts that presently provide passage for Coal Creek with a bridge or elevated highway section would provide the best connectivity in this area. Any new structure should provide natural stream-bed substrates, encompass stream banks with upland vegetation that could be used by animals during normal stream flows, and eliminate the barriers imposed by the hanging downstream ends of the existing culverts. Channeling animal movement into crossing structures in this area would be difficult. Installation of fencing in this area may not be practical due to maintenance challenges associated with the heavy snow load. Road-kill levels in this area are not high. Installation of a crossing structure without fencing in this area could be a possibility. Installation of extra-tall Jersey barriers or concrete walls may also help to redirect animal movement to crossing structures associated with Coal Creek. Management for late successional forest characteristics and reduced levels of human disturbance in sections 10 and 16 will also be important for maintaining or enhancing the value of this area for animal movement.

Gold Creek / Keechelus North

This area connects the gentle terrain of the Gold Creek valley with habitat on the west side of Keechelus Lake and the seasonally de-watered lake bed. We believe that this area provides the best existing connectivity for animals moving through the I-90 corridor in the Cascade Crest area. The Forest Service and Bureau of Reclamation own the land in this area. However, increased residential development in the Gold Creek valley could impact the future value of this area for wildlife movement.

Existing bridges at Coal and Gold Creek provide some potential connectivity opportunities. The value of the Coal Creek bridge for wildlife connectivity is limited by its proximity to the Hyak WSDOT Maintenance area and Hyak Sno-Park. Developing and maintaining riparian forest vegetation along Coal Creek to provide a visual buffer for animals moving along the stream may enhance wildlife passage through this structure. Utility of the Gold Creek bridge for animal movement is limited depending on the level of water in Keechelus Lake. The value of this area for wildlife movement would be improved by reducing the level of Keechelus Lake to prevent or limit the duration of inundation of the entire streambed under the bridge. Another possibility could be to dredge and fill to create a strip of upland habitat through the Gold Creek bridge and across the north end of the lake. Any modification of the northern end of the lakebed should be combined with re-vegetation to promote the development of late successional forest habitat characteristics to provide connectivity for late successional associates in this area.

Fencing or other guiding structures (such as walls or high jersey barriers) should be considered for this area. Concerns about maintaining fences under heavy snow loads are an issue here. Enhancement of the bridges at Coal and Gold Creeks without installing fencing would not re-direct animal movement into these structures and collision rates would not be reduced in this area.

9.3) Keechelus Lake – Amabalis Mtn.

Wildlife movement in the area between Keechelus Lake and Amabilis Mountain is concentrated between the Keechelus Lake dam and the Cabin Creek exit (mileposts 61 – 64). Land ownership in this area is mixed, though provisions were made for forest service acquisition of these lands in the I-90 Land Exchange final agreement. This area may provide the best connectivity for wildlife movement in the future due to residential development and recreation pressures in other portions of the study area, particularly Snoqualmie Pass and the Yakima Valley. Connectivity models predict that wildlife movement through the Yakima River Valley is already limited by development. Future development of the Price Creek Rest Area and re-opening the rest area for year-round use could influence the value of this area for wildlife movement.

Data from road kill locations and snow tracking transects indicate 3 potential connectivity areas in this highway section. These areas are:

1) The area just east of the Keechelus Lake dam to the Price Creek rest area (milepost 60.9 to 61.2) where both deer and elk collision levels were second highest in the study area.
2) The area from approximately 0.2 miles east of the Price Creek rest area to Crystal Springs Campground (milepost 61.9 to 62.2) where a cluster of 5 coyote crossings were recorded in 2000 and where mountain lion sign and a road killed mountain lion carcass were documented in 1999.
3) The area between the Stampede Pass and Cabin Creek exits (milepost 63.3 to 63.7) where a cluster of 3 bobcat and 5 coyote crossings were recorded during the 2 winters of snow tracking.

Due to the relatively high level of animal use and the potential future importance of this area, consideration should be given to placement of animal crossing structures here. Options for permeability enhancing structures in this area include portions of elevated highway, overpasses, or underpasses. Elevated highway segments or expanded bridges in the 3 area identified above would be likely to provide the best permeability for animal movement. An extensive system of guiding fences would not be needed with elevated highway segments, because the elevated portion of highway would be inaccessible to animals.

A wide wildlife overpass crossing (approximately 100 to 150 meters of road length) similar to those installed in Europe and Canada could also provide wildlife crossing opportunity. A system of guiding fences would be needed to channel animal movement onto such a structure. Such a system of fencing would be problematic in this area due to the heavy snow load.

Good locations for installation of wildlife underpasses are limited in this area. An underpass could be placed in replacement of the Price Creek box culvert (C61A). Another structure could be located in the draw at milepost 63.8. Other natural draws or likely locations for underpasses have not been identified along this section of highway. Locations for other wildlife underpasses would probably have to be excavated under the highway. An extensive system of guiding fences would be particularly important if wildlife underpasses were installed because many species are more hesitant to use these types of structures.

Management of landscape-scale habitat connectivity in this area should focus on regenerating late successional forest characteristics and improving habitat security in the area between Keechelus Ridge (T21N, R12E, section 2) and Dandy Pass (T21N, R11E, section 22), including the area just southeast of the Keechelus Dam (T21N, R11E, section 12).

9.4) Easton Hill

Easton Hill provides the best existing connectivity for forest wildlife in the study area. The combination of forest habitat and highway configuration make this area relatively permeable for wildlife movement. Future residential and recreational development has the potential to compromise the value of this area for wildlife movement. The western half of the hill is in Forest Service ownership. The area along the Kachess River is under Washington State Parks ownership. Much of the area between is private.

Wildlife habitat connectivity could be enhanced in this area by providing wildlife crossing overpasses on Forest Service land in the western portion of the hill. Crossing overpasses could be installed near the lane split at the west end of the hill (milepost 67.2) and take advantage of existing topography. This location has the highest density of elk road-kills in the study area, and crossings by coyote and bobcat have been documented during tracking surveys here. Crossing structures near milepost 67 would be buffered from recreational activity and residential development in the vicinity of Easton State Park.

Other locations along Easton Hill would likely be less effective because of human disturbance. One possible approach is to provide for animal movement along the Kachess River by constructing a wildlife crossing structure at the bottom of Easton Hill (milepost 69.2). However, extensive human activity in this area would compromise the effectiveness of a structure in this area. Implementation of a crossing structure here would provide connectivity between riparian forest along the Kachess River and the western portion of Easton State Park. A crossing structure in this area would also have to provide passage across the frontage road north of the highway. Wildlife crossing structures in this area would be likely to receive extensive human use due to their proximity to Easton State Park. Moderate to high levels of human use have been correlated with low animal crossing frequency at highway crossing structures in Banff National Park, Canada (Clevenger 1999). Extensive human use could compromise the effectiveness of a structure along the Kachess River.

Modification of the Kachess River bridge to provide streamside habitat for wildlife movement would not be likely to provide passage for animals sensitive to human disturbance. Value of this option would be limited by recreational activity along the Kachess River near Easton Park. Modification of the I-90 bridge over the Kachess River would also have to be accompanied by modification of the bridge for the frontage road north of I-90 and the historic bridge south of I-90. Vegetation providing a visual buffer in this area is also limited. Any facility to provide for animal movement in this area would be likely to be used extensively by people.

9.5) Yakima River Valley

Development of wildlife connectivity areas in the Yakima River Valley bottom is difficult because of the level of suburban development and lack of well connected forest habitat in the valley. Development of wildlife movement corridors in this area would necessitate acquisition of numerous small private land parcels to develop habitat connectivity. Public lands acquired for wildlife habitat in this area may become de facto parks and are likely to be heavily used for recreation. Opportunities for people, as well as animals, to cross I-90 are limited. Wildlife crossing structures located close to residential developments are likely to be used extensively by people, limiting their utility to sensitive wildlife. Consideration should also be given to the potential for conflict in developing animal movement corridors that could encourage movement of large carnivores through residential areas.

Existing animal movement areas in the Yakima River Valley appear to be Tucker Creek to west of Lavender Lake (milepost 73 to 73.5), east of Lavender Lake to Big Creek (milepost 74.5 to 75), and the Cle Elum River (milepost 81). Crossing opportunity could be enhanced with wildlife overpasses on either side of Lavender Lake, though snow tracking surveys during winter 2000 recorded more animal movement activity between Lavender Lake and Big Creek (figure 6.2). Crossing structures in this area would require extensive fencing installations to channel animal movement to the structures. Any crossing structure should be long enough to provide passage over the railroad on the south side of the highway. Even though the railroad itself probably does not constitute a barrier to animal movement, it would be inappropriate to fence off the highway but not the railroad. Consideration would also need to be given to the presence of the John Wayne Trail along the south side of the highway and what, if any, measures to discourage pedestrian use of animal crossing structures may be taken. Land would need to be purchased on both sides of the highway to provide secure habitat along approaches to any structures installed.

Some crossing opportunity is currently provided by the bridges at Big and Little Creeks (mileposts 75.3 and 76). Humans, dogs, and deer were detected crossing through these structures during monitoring in 1998. These bridges are popular summer recreation areas and are likely to be of limited value to animals sensitive to human disturbance, however modification of these structures to provide vegetated stream banks and maintenance of secure habitat along the approaches to these structures could enhance habitat connectivity for species less sensitive to human disturbance and could provide a more cost-effective alternative to constructing dedicated animal crossing structures.

Installation of a system of fences and underpasses in the Bullfrog area may be appropriate due to the relatively high frequency of collisions with deer in this area. Installation of structures to minimize deer collisions along this portion of highway would not be likely to improve landscape permeability for late successional wildlife. A cost-benefit analysis for such an installation could be conducted to determine if the frequency of collisions in this area justifies implementation of a system of fences and underpasses. This road-kill concentration area extends from the Yakima River bridge at milepost 79 to east of the Cle Elum River at milepost 82.5. Fencing could be installed in this area on both sides of the highway from the bridge over the Yakima River at Sun Country to Cle Elum. Fencing could channel animals to the Cle Elum River bridge on the west bank of the river. Crossing underpasses would need to be installed at milepost 79.2 (just west of the new weigh station) and in at least 2 locations east of the Cle Elum River.

10) Future Research

Surveys conducted during this study have provided useful information in determining what animals approach and cross the highway in what areas. However, it was not within the scope of this study to address important basic ecological questions about the effects of a major highway on animal ecology and population dynamics. Important questions that will require substantial investment in intensive telemetry studies and genetic analysis include:

- To what distance does the presence of the highway and highway associated disturbance influence animal use of habitat near the highway?
- How do these influences affect how animals move through the highway corridor?
- Does mortality associated with the highway affect population dynamics for wildlife near the highway?
- Does exclusion from otherwise suitable habitat close to the highway affect wildlife populations across a broader landscape?
- To what extent do highway disturbances and physical barriers limit dispersal movements and contribute to population isolation?

Basic research is needed on the dispersal behavior of species of management concern in the central Cascades, particularly addressing the effects of natural and anthropogenic barriers on population isolation. Demography studies are needed to determine if there are population effects from major roadways on wildlife in the area. Telemetry studies to document inter- and intra- territorial movement of animals in relation to major highways should be a priority. Genetic analysis should be conducted to determine degrees of relatedness between populations separated by highways and natural barriers. Additional work on characteristics of drainage structures used by smaller animals in crossing the highway would also be useful in managing for multi-scale permeability of highway corridors. Finally, continued monitoring of identified connectivity areas should be conducted to provide baseline data to evaluate the effectiveness of any mitigation measures that may be implemented to improve landscape permeability. Continued systematic monitoring of any crossing structures will be essential for evaluating the success of such projects.

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